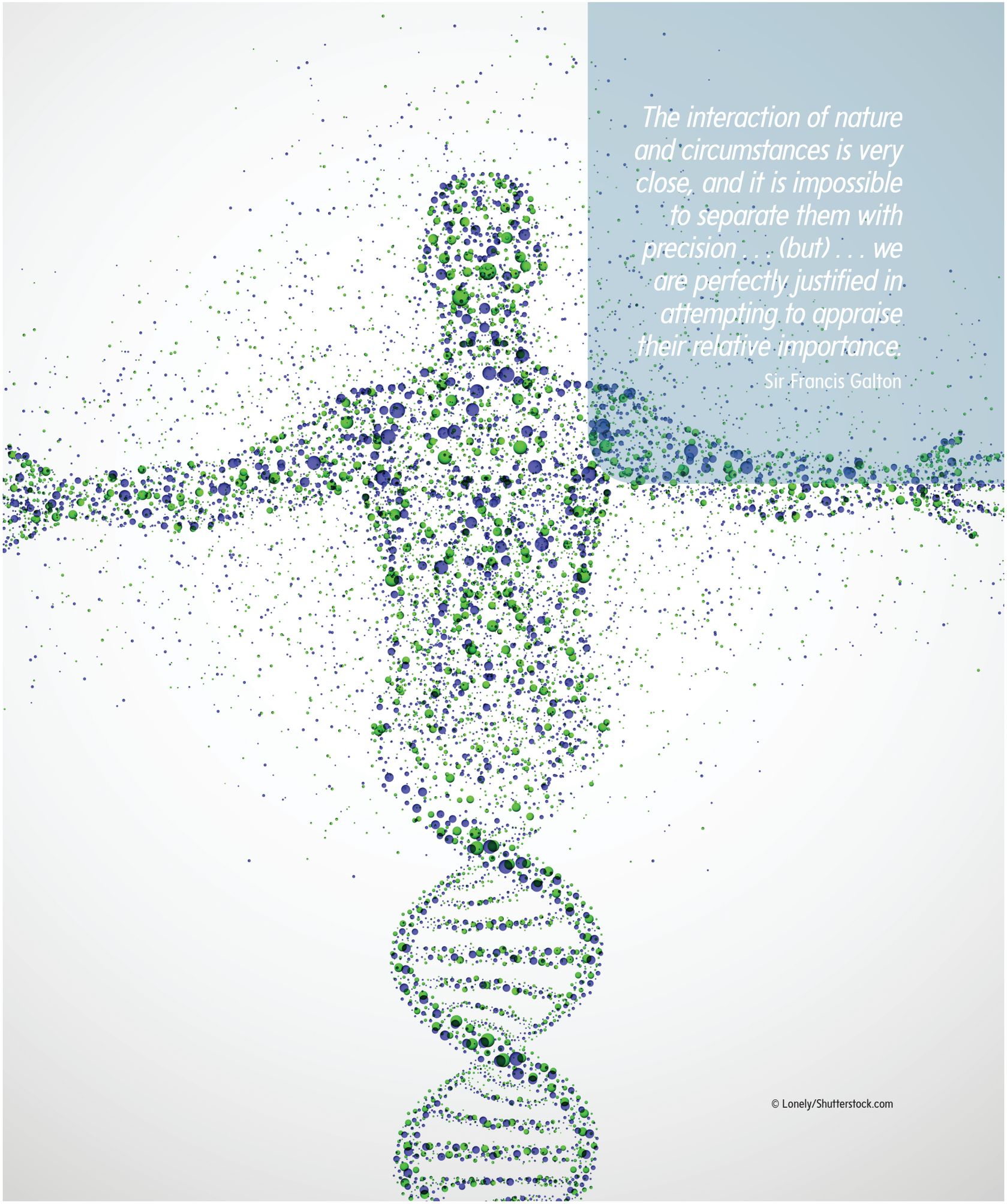

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Evolution, genes, environment and behaviour

3

with Deborah Custance

Chapter Outline

EVOLUTION BY NATURAL SELECTION

- Natural selection

MENDELLIAN GENETICS

- Genes and chromosomes

INHERITED BEHAVIOURAL ADAPTATIONS

- Ethology

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- Adoption and twin studies
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- How the environment can influence gene expression
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- For the good of the gene

Applying psychological science

- Evolutionary approaches to human mate choice
- Evolutionary approaches to personality

Research close-up *Sex differences in the ideal mate: evolution or social roles?*

On 20 June 2000, the American President, Bill Clinton, and the British Prime Minister, Tony Blair, made a joint announcement to the world's press. They declared the first survey of the mapping of the entire human genome. President Clinton stated that, 'Without a doubt, this is the most important, most wondrous map ever produced by human kind'.

On 18 December 2013, an international team of scientists revealed to the world that they had mapped the entire genome of a Siberian Neanderthal woman from her 130,000-year-old toe bone (Prüfer et al., 2014). Most scientists assume that Neanderthals (*Homo neanderthalensis*) were not the direct ancestors of modern humans (*Homo sapiens*). Instead, the fossil and DNA evidence suggests that they diverged from the human lineage between 700,000 and 370,000 years ago and went extinct around 60,000 years ago (Noonan et al., 2006). Although the recent Neanderthal genomic map supports such a view, there was also evidence of interbreeding between Neanderthals and humans. Neanderthals went extinct, but it seems that some of their genes survive in modern humans today. Thus, we not only carry our direct ancestor's evolutionary past with us in our genes, but also that of an extinct hominid relative.

In fact, the vast majority of species in the history of life on Earth have, like Neanderthals, ended as evolutionary dead ends, consigned to the dustbin of extinction. Only a fraction of all species that have ever existed has survived through to the present day. Every living creature can, in theory, trace his or her lineage back through the Tree of Life in an unbroken chain to the first self-replicating organism in the primordial soup (Figure 3.1). If even one of your ancestors had not behaved effectively enough to survive and reproduce, you would not be here to contemplate your existence. Thus, you are an evolutionary success story and your very existence is little short of a miracle. The biological units that have been bequeathed to you by your ancestors are genes, which are functional segments of a long molecule called deoxyribonucleic acid or DNA. As descendants of successful forebears, you carry within you genes that contributed to their adaptive and reproductive success. It seems that some of us are also carrying a few genetic hitchhikers from long-gone Neanderthals.

Why Should Psychologists Study Evolution and Genes?

Although undoubtedly a cause for fascination and awe, you might be wondering why psychologists should concern themselves with evolution and genes. Surely evolutionary theory is the proper subject of biology, not psychology? When one thinks of evolution, one tends to think of gradual *physiological* changes that occur over eons of time. In terms of human evolution, one thinks of hairy, heavy browed, knuckle-walking apes that changed over time into fine-featured, hairless bipeds (i.e., creatures that walk habitually on two legs). As the title of this book indicates, psychologists are primarily concerned with the science of mind and behaviour, not physiology. Yet, physiology is intimately related to cognition and behaviour. There can be no thinking and behaviour without the physical substrates of brain and body; and there can be no brain and body without genes. The particular set of genes an individual possesses came about in turn during the course of evolution. So to understand fully brain and behaviour, one must consider genes and their selection during the course of evolution.

Since the brain is the seat of all thought, it is naturally an object of fascination for psychologists. Yet the fossil evidence suggests that the human brain did not just pop into existence fully formed. The remains of crania from long dead hominids (i.e., the 20 or so species of bipedal ape, including modern humans, that diverged during the course of evolution away from the other great apes) suggest our ancestors' brains underwent a dramatic and rapid process of change. Early hominids such as *Australopithecus* had brains about the size of modern chimpanzees (Figure 3.2). What made them distinctly human was not their brain size so much as the fact that they were semi-bipedal. Over the course of one to two million years, from about 1.6 million to 100,000 years ago, the human brains tripled in size (Schwartz et al., 2004; Figure 3.2). No other species has undergone such a dramatically rapid expansion in brain size (Dorus et al., 2004). There must have been extraordinary selection pressures for the human brain to change so profoundly in such a relatively short period of time.

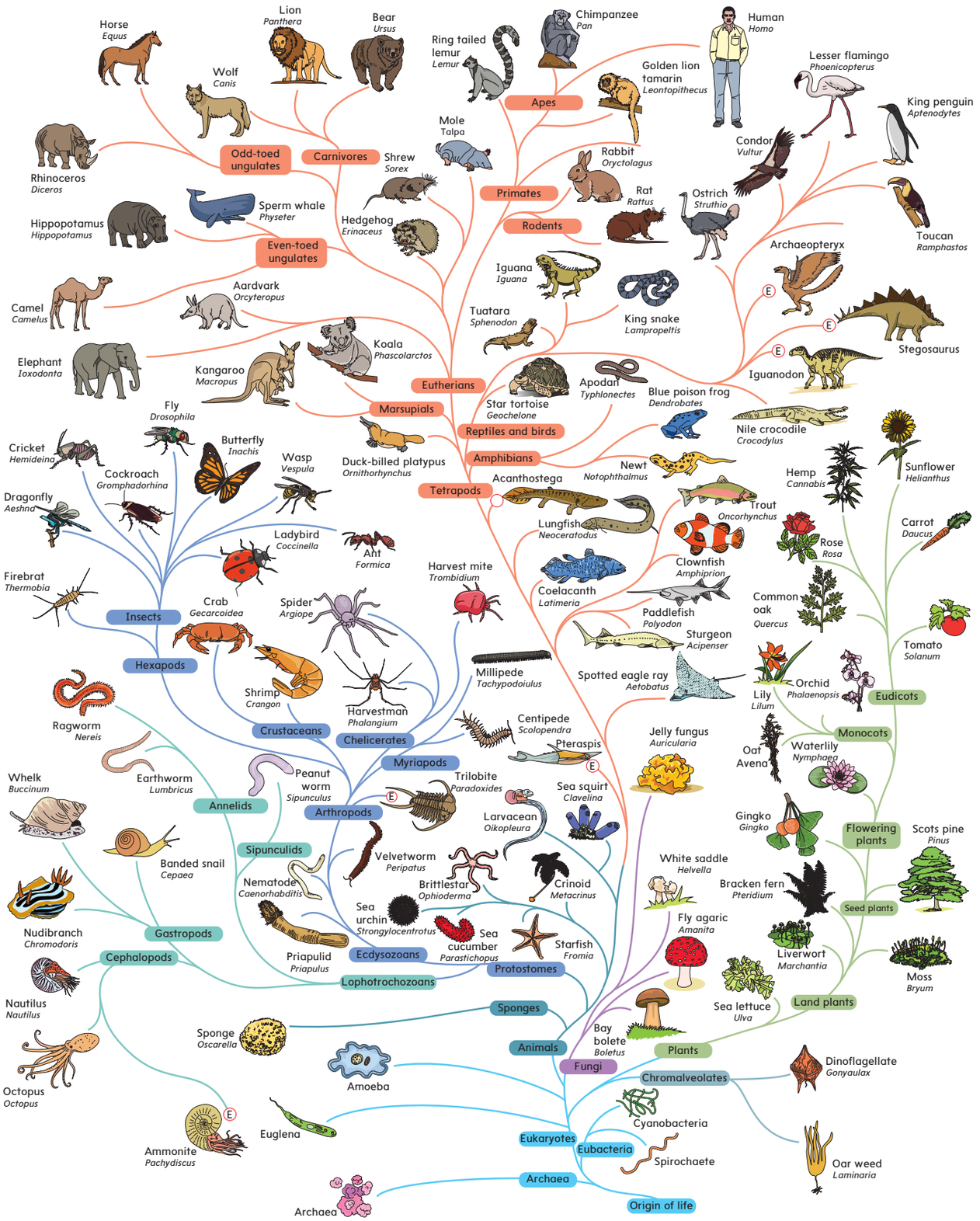

FIGURE 3.1 The Tree of Life

The branches culminating in extant (i.e. not extinct) species can be considered evolutionary success stories.

Source: Based on and adapted from The Tree of Life from The Open University

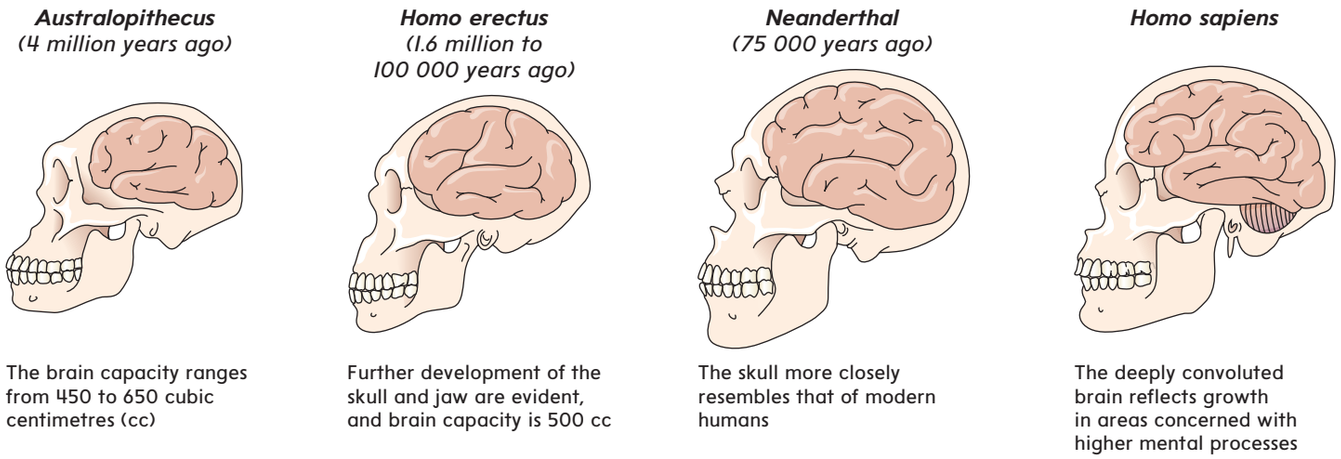

FIGURE 3.2 The fossil record indicates that the human brain tripled in size from 1.6 million to 100,000 years ago. The greatest growth occurred in those areas concerned with the higher mental processes, particularly memory, thought and language. Current thought is that Neanderthal man took a different evolutionary route from Homo erectus, and is thus not our ancestor.

How could such rapid and dramatic changes in the human brain take place? Part of the answer must lie in our genes. Genes carry the blue print for making our whole body, including our brain. In fact, it is estimated that about half of all our genes target brain structure and function (Kolb & Whishaw, 2003). Working out how genes guide the constructions of brains and turn brain functions on and off is one of the major current endeavours of brain science (Allen Institute for Brain Science, 2006; The Big Brain Project, 2013).

Genes are not only of relevance to psychologists in terms of how they code for and build brains, but also with respect to how they affect behaviour. The question of nature versus nurture has fascinated thinkers for centuries. To what extent can we say that any particular class of behaviour is the result of learning versus inherited tendencies? Do humans and animals enter the world as *tabular rasa* or blank slates so that everything they go on to do is the result of learning in the environment? Or do we enter the world with innate behavioural predispositions that allow us to adapt quickly to certain environmental challenges without every generation having to learn the proper form of response from scratch?

behavioural genetics a field of psychological science dedicated to investigating how genes and the environmental factors interact during the course of development so as to affect behaviour

evolutionary psychology a field of psychological science that investigates the evolutionary origins of various psychological traits

Behavioural genetics is a field of psychological science entirely dedicated to investigating how genes and the environment interact during the course of development so as to affect behaviour (Plomin, Haworth, Meaburn, & Price, 2013). Behavioural geneticists have developed ever more elegant techniques for modelling the relative contributions of genes and the environment to various personality and behavioural traits. Since each of us has inherited our own personal complement of genes from our evolutionary ancestors, any genetically influenced behaviours are likely to be adaptations to ancestral problems. Thus although evolutionary theory is undoubtedly the overarching paradigm within the biological sciences, since genes affect mind and behaviour, they and their origins must also command the attention of psychologists.

There is yet another branch of psychological science, **evolutionary psychology**, the practitioners of which investigate the evolutionary origins of various psychological traits. Evolutionary psychologists argue that important aspects of human psychology and social behaviour, including aggression, altruism, nepotism and mate choice to name but a few, are influenced by evolved biological mechanisms (e.g., Dawkins, 2006; Morris, 1967; Buss, 2013). Instead of primarily focusing on genes, evolutionary psychologists develop hypotheses based upon evolutionary theory, which is often developed from observations of animal behaviour, to help explain human behaviour. Evolutionary psychologist David Buss says: 'Humans are living fossils – collections of mechanisms produced by prior

selection pressures' (1995, p. 27). If Buss and the other evolutionary theorists are right and humans possess inherited behavioural and psychological predispositions, then considering human psychology within the context of evolutionary theory could provide invaluable insights into the human condition (Tooby & Cosmides, 1992).

In this chapter, we are going to consider our evolutionary past and genetic present. How do the genes that we have inherited from our forebears interact with present day environmental influences and in turn affect our psychology and behaviour? First, we will examine Charles Darwin's theory of evolution by natural selection. How and why are certain physical and behavioural traits selected over others during the course of evolution? Next we will consider Gregor Mendel's elegant solution, in the form of genetic inheritance, to the puzzle of how traits are biologically encoded and passed on from parent to child. In the following section, we examine the field of behavioural genetics, which models the interaction between genetic and environmental factors in the development of various personality traits and behavioural tendencies (e.g., Bouchard, Lykken, McGue, Segal, & Tellegen, 1990; Plomin & Spinath, 2004), Finally, we return to the question of human nature. What can the synthesis of evolutionary theory and genetics tell us about such important aspects of mind and behaviour as mate choice and personality? (Wright, 2010).

As we see throughout the book, this biological level of analysis provides us with key insights into behaviour and its causes. The knowledge gained in this chapter will give you the background needed to understand much of the behaviour discussed in chapters that follow.

EVOLUTION BY NATURAL SELECTION

Evolution refers to gradual change over time. *Biological* evolution refers to gradual change in organic life that may eventually lead to the formation of new species. Before Charles Darwin published *The Origin of Species* in 1859, most Westerners believed that life on Earth had been created fully formed in a single moment in time and remained relatively unchanged from that point to this. In contrast, the theory of evolution suggests that life on Earth has been subject to a slow, but inexorably powerful process of change. In fact, Darwin was not the first person to suggest that life on Earth has changed over time. Several people had proposed theories of evolution prior to Darwin, including his own grandfather, Erasmus Darwin (who even composed a poem on the subject). What made Charles Darwin's ideas so important was that he was first person to suggest a viable mechanism by which biological evolution could take place. He called that mechanism **natural selection**.

evolution (biological) gradual change over time in organic life from one form into another

natural selection characteristics that increase the likelihood of survival and reproduction within a particular environment will be preserved in the population and therefore become more frequent over time

NATURAL SELECTION

Long before Darwin published his theory of evolution, people knew that animals and plants could be changed over time by selectively breeding members of a species that shared desired physiological, temperamental or behavioural traits. A visit to a dog show illustrates the remarkably varied products of selective breeding of pedigree animals. Genetic analysis has revealed that all breeds of domestic dog, from Chihuahua to Great Dane, were originally derived from the gray wolf (Freedman et al., 2014; Figure 3.3). Yet the domestic dog breeds differ markedly from the gray wolf and each other both in appearance and behaviour.

Just as plant and animal breeders 'select' for certain characteristics, so too does nature. Of course, selection in nature is not consciously directed as it is in human breeding programmes. Natural selection is an undirected

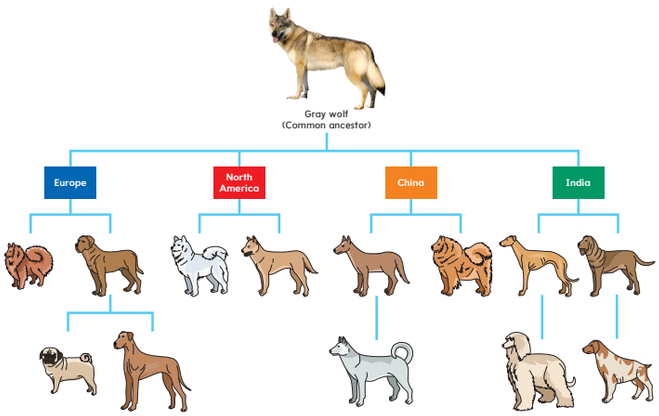

FIGURE 3.3 **The common ancestor to all domestic dog breeds is the gray wolf (*Canis lupis*). Human-initiated selective breeding over a number of generations has produced a wide array of pedigree dog breeds.**

Source: Based on Discover Biology 2e W.W Norton and Company

FIGURE 3.4 The thick coat of the Arctic wolf makes them well adapted to their cold, mountainous environment.

Source: ©iStock.com/Cybernesco

or 'blind' process based upon three factors: (1) biological variation; (2) high reproduction rates and the fact that not all members of a population survive; and (3) competition over limited resources (Lewin, 2005). The individuals of any given species biologically differ from one other. Some of those differences may convey an advantage in terms of survival and reproduction. For example, some members of a particular prey species may possess more acute hearing than others and hence be better able to detect and avoid predators. If those adaptive traits are heritable, that is, can be biologically passed on from parent to infant, then over time they will increase in frequency in the population.

It is easier to understand how natural selection works when one considers a concrete example. Imagine a population of wolves that live in a hot, dry climate. The wolves slightly differ from one another in their degree of furriness. Some of them are very thin-coated, while others have a slightly thicker covering of fur. Now imagine that the climate changes: it becomes considerably colder and as a consequence there is less to eat. Those wolves that are better insulated by their slightly thicker fur are more energy efficient and can survive on less food. If the furry trait is heritable then the offspring of the furriest survivors will also be better adapted to the climate and more likely to survive and reproduce in their turn. As a result, the next generation of wolves will be that bit furrier than the last. If the temperature continues to plummet, in future generations it is again the furriest individuals who are most likely to win through in the competition for food and mates. If the process continues from generation to generation, the final result may be a population of wolves that look very different from their thinly coated forebears. Indeed, in nature we find that thick-coated species of extant wolves, such as the Arctic wolf (*Canis lupus arctos*) live in cold climates (Figure 3.4), while thin-coated species such as the Indian Wolf (*Canis lupis pallipe*s) live in hot climates (Figure 3.5). Notice also how the wolves differ not only in the thickness of their fur, but also their colour.

Focus 3.1 Describe how natural selection might change a population of rabbits with relatively poor hearing into a population with very acute hearing. What change in the environment might trigger the selection of sharp-eared rabbits?

Natural selection not only affects physiological features such as degree of furriness, but also behavioural traits. We can again see this in dogs and wolves. When Axelsson et al. (2013) directly compared the genomes of dogs and wolves, the largest areas of difference were related to brain function and nervous system development. Research has shown that dogs and wolves differ in the way they interact with humans even when both have been raised in human households as pets. Hare, Brown, Williamson and Tomasello (2002) found that dogs followed a human's pointing and eye gaze cues to locate hidden food significantly better than wolves. When Miklosi, Kubinyi, Topal, Viranyi and Csanyi (2003) replicated these findings, they found that the crucial difference between the species was that wolves looked back at humans much less than domestic dogs do. We cannot easily explain these findings in terms of differences in learning or experience, since both species in these experiments had been raised in a similar manner. Thus it would seem that differences in quite surprisingly subtle behaviour such as visually orienting to humans are under the influence of inherited biological factors.

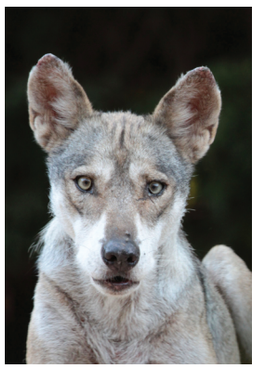

FIGURE 3.5 Indian wolves have a relatively thin coat of hair, which makes them well adapted to the hot Indian climate.

Source: ©iStock.com/yairleibo

Although dogs and wolves provide a neat example of artificial and natural selection, there is a vital element missing in the above account. How do new traits emerge in a population? In the example of wolf evolution, where does the extra fur come from in each new generation? If organisms faithfully inherit parental characteristics, then the wolves should not exceed the furriness of the parental stock. Darwin was unable to answer such questions, since he was wholly ignorant of the mechanisms of inheritance; as were indeed all his peers except for one, the father of modern genetics, Gregor Mendel. The answer is related to genetic mutation. **Mutations** are random events and accidents in gene reproduction during the division of cells. If mutations occur in the cells that become sperm or eggs, the altered genes will be passed on to offspring. Mutations help create variation within a population's physical and behavioural characteristics. It is this genetic variation that makes evolution possible. Thus, to understand fully how evolution occurs one must take into account the role of genes.

mutations random events and accidents in gene reproduction during the division of cells

In review

- Biological evolution refers to gradual change in organic life that may culminate in the emergence of new species. Charles Darwin was the first person to suggest a viable mechanism by which evolution could occur: natural selection.
- Natural selection is based upon biological variation, high reproduction and mortality rates and competition over limited resources. If a biologically variable and heritable trait conveys an advantage in terms of higher reproductive success that trait will increase in frequency in a given population.
- Genetic mutation is necessary if biological variation is to exceed the sum of a trait found in the parental stock of a population.

MENDELLIAN GENETICS

Nowadays we know that genes are the means by which we inherit not only physiological, but also certain behavioural, perceptual and temperament or personality traits. Scientists in Darwin's day were fascinated by patterns of biological inheritance. Darwin himself became a keen pigeon-fancier in order to study their inherited differences due to selective breeding. To that end, he collected and bred every known breed of pigeon in Victorian Britain. He noted differences not just in terms of the pigeon's body shape and plumage, but also in their behaviour. Some of them cooed in distinctive ways and others flew in odd ways: the tumbler literally tumbles from the sky when it descends in flight. Just as domestic dogs are all derived from the gray wolf, all domestic pigeons are derived from one wild species of bird, the rock dove (*Columba livia*). All the observed physiological and behavioural differences in domestic pigeons must somehow be 'hidden' within the biology of rock doves. Although Darwin could control the breeding of his domestic birds and thereby vary some of these traits, he was at a complete loss as to explain the underlying biological mechanisms.

Actually, birds are particularly good subjects for considering the effects of biological inheritance on behaviour. Many species of bird perform elaborate and complex behaviour, such as constructing complicated nests or following long migration routes, even when they have been raised in captivity and had no opportunity to learn from other members of their own species (Jenson, 2009). Dilger (1962) performed cross-breeding experiments on lovebirds that showed the effects of inheritance on nesting behaviour. Lovebirds are small African parrots. They make nests by lining holes in trees with strips of bark. Fisher's lovebirds (*Agopornis fisheri*) carry single strips of bark in their beaks. Peach-faced lovebirds (*Agopornis roseicollis*) transport several pieces of bark at once by tucking them into their flank and rump feathers. Dilger cross-bred Fisher's and peach-faced lovebirds and found that the resultant offspring performed a confused and intermediate pattern of nesting behaviour. Young captive hybrid birds tore off strips of paper, tucked them into their rump and flank feathers, but then would not release them from their beaks and would take them out again, repeating these actions over and over. It was as if the two behaviours, 'carry in beak' and 'tuck in feathers', were both biologically preserved in the birds, but working in direct conflict with each another. Thus, it seems that quite specific behaviours can be subject to biological influence. Yet, what exactly was passed on biologically from parent to chick that could affect the young birds' behaviour in this way? Dilger knew that it was something to do with the birds' genes, but he could not study their pattern of inheritance systematically beyond the first generation since all the hybrid birds were sterile. Yet, Darwin and all his contemporaries (except for one, the father of modern genetics, Gregor Mendel) knew nothing of genes.

The lack of a satisfactory theory of biological inheritance constituted a gaping hole in Darwin's theory of evolution by natural selection. The most widely accepted model of inheritance during Darwin's lifetime, and the one he eventually subscribed to, was Blending Theory. Blending suggests that parental traits are blended together rather

like mixing white and red paint to produce pink. The problem with blending is that it is incompatible with natural selection (Jenkin, 1867). Blending traits eliminates variability. Thus, if one mixes all the paints in a paint box, one will end up with a murky uniform brown colour and lose the original wide array of colour choices. Without variability natural selection cannot operate because it has nothing to select among. Thus if blending were true for every inherited trait, be it physiological or psychological, one would eventually end up with the mean or average pattern. Everyone would have the same basic personality, the same intelligence, the same hair and eye colour and so on. Any differences in behaviour would be purely due to learning from the environment. Yet the very variety that emerges from selectively breeding pigeons and dogs belies blending. The great puzzle of inheritance was eventually solved in the 1860s by a relatively unknown Austrian monk, Gregor Mendel (see Henig, 2001). Unfortunately, the relevance of Mendel's work was not fully recognized until the early decades of the twentieth century.

Mendel, however, did not concentrate upon the inheritance of behavioural traits. He was trained in both physics and plant physiology and was renowned as a plant breeder. He worked out the laws of inheritance by conducting elegant experiments on pea plants. The pea plant offers a very simple model for understanding the laws of genetic inheritance. So although peas are of very little psychological relevance, we will study Mendel's classic experiments in order to help us understand the fundamentals of genetic inheritance. We will then explore how these simple laws that apply to peas can be used to explain the inheritance of certain psychological conditions in humans.

Mendel was fascinated with the variations he saw in plants of the same species. For example, the humble garden pea has several strictly dichotomous characteristics. It can produce either white or purple flowers; long or short stems; yellow or green pods with an inflated or constricted shape; and yellow or green seeds (or peas as they are more commonly called) with wrinkled or smooth skins (Figure 3.6). Best of all, from a research perspective, pea plants are very well suited to breeding experiments. They normally self-fertilize, but one can easily artificially control their fertilization so as to combine the dichotomous features one is interested in. In a series of elegantly controlled experiments, Mendel did exactly that, carefully recording the features of the resultant offspring. Let's consider his findings with respect to pea colour in more detail.

dominant the particular characteristic that it controls will be displayed

recessive the characteristic will not show up unless the partner gene inherited from the other parent is also recessive

The variety of pea plant Mendel chose, *Pisum sativum*, produces either all green, all yellow or a mixture of green and yellow peas. First, Mendel grew plants that produced either all green or all yellow peas. When they had bred true for two years, that is, they only produced one or other of the two pea colours; they formed the baseline parent generation (P). Mendel prevented parental plants from self-fertilizing and manually cross-fertilized them. The resultant peas in the following generation (f1) were all yellow: the green characteristic had completely disappeared (see Figure 3.6). Mendel then planted those yellow peas and allowed the resultant plants to self-fertilize. When he opened up the pea pods of these plants (f2), he found that the green trait had re-emerged. There was an overall ratio of three yellow peas to one green pea inside the pods. He then planted these peas, let the plants self-fertilize, and examined the peas they produced (f3). The green peas grew into plants that only produced further green peas (see bottom far right of Figure 3.6). One third of plants grown from the yellow peas produced all yellow peas (see bottom far left of Figure 3.6). The remaining plants produced that magic ratio of three yellow peas to one green pea again.

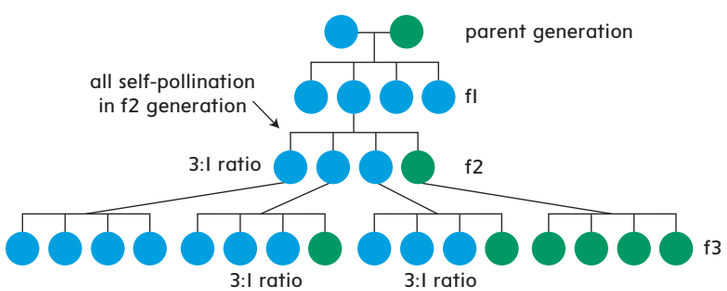

FIGURE 3.6 The pea colour ratios produced in Mendel's breeding experiments from one generation to the next.

The importance of Mendel's work was the elegant way in which he explained his findings. Since the cross-fertilized plants only produced yellow peas, Mendel proposed that yellow was a **dominant** trait while green was **recessive**. Yet, since the yellow peas from the cross-fertilized plants grew into plants that

produced both green and yellow peas, they must still have been carrying the green trait, but unexpressed. Mendel proposed that heredity factors, that is, genes, must come in double doses – each of which is called an **allele**. The particular combination of dominant and recessive alleles determines the outwardly expressed characteristic of an organism or its phenotype.

allele alternative forms of a gene that produce different characteristics

homozygous organisms that possess the same type of allele for a trait, either two dominant or two recessive

heterozygous organisms that possess different allele for a trait, one dominant and one recessive

genotype the specific and complete genetic make-up of the individual

phenotype the individual's outward observable characteristics

Geneticists use a standardized form of notation in which dominant alleles are represented by capital letters and recessive alleles are expressed in lower case. In terms of pea plants, peas that contain two dominant alleles (AA) produce plants that breed true for yellow peas. Peas that contain two recessive alleles (aa) produce plants that breed true for green peas. And peas that contain one dominant and one recessive allele (Aa), express the dominant yellow trait, but continue to carry the recessive allele within them. You can see that these traits are modular, at no point are they blended. Thus, Mendellian inheritance retains the biological variation needed for natural selection to operate.

Gametes or sex cells (eggs or sperm) differ from other cells in that they only carry one allele. The complementary pairs of alleles come together in different combinations during fertilization. Organisms that receive the same alleles, that is, two dominant or two recessive, for a trait are called **homozygous** and organisms with different forms of alleles, one dominant and one recessive, are called **heterozygous**.

Early in the twentieth century, geneticists made the important distinction between **genotype**, the complete genetic code of the individual, and **phenotype**, the individual's outwardly observable characteristics (Johannsen, 1911). Genotype is present from conception, but phenotype can be affected both by other genes and by the environment. The same phenotype can have different genotypes. As we saw in Mendel's peas, yellow peas can be based on a genotype of either AA or Aa. The same is true in humans. In humans, for example, brown eyes are dominant over blue eyes. A child will have blue eyes only if both parents have contributed recessive genes for blue eyes so that she is homozygous for the recessive trait (bb). If a child is heterozygous so that she inherits a dominant gene for brown eyes from one parent and a recessive gene for blue eyes from the other (Bb), she will have brown eyes and the blue-eyed trait will remain hidden in her genotype. Eventually, the brown-eyed child may pass the recessive gene for blue eyes to her own offspring (Klug, Cumings, Spencer, & Palladino, 2009). Just as the same phenotype can have different genotypes, the same genotype can have different phenotypes. Identical twins have the same genes, but if one eats more than the other they will differ in the phenotypic expression of body weight (Plomin et al., 2013). One helpful analogy might be to think of it as a genotype being like the software commands in your word-processing program that allow you to type an email; while phenotype is like the content of the email that appears on your computer screen.

The basic principles that govern the inheritance of seed colour in pea plants also govern human inheritance as we have already seen with respect to brown and blue eye colour. Now that you understand these basic principles we can use them to better understand directly psychologically relevant conditions. Phenylketonuria and Huntington's disease manifest themselves primarily in terms of psychological malfunctioning. They are both based upon the inheritance of specific combinations of the alleles from single genes.

Phenylketonuria

Phenylketonuria or PKU is associated with developmental delay and severe learning difficulties (Williams et al., 2008). It occurs at a rate of approximately one in 10,000 births. Before the biological cause of PKU was discovered, it is estimated that 1% of people placed in mental institutions were suffering from PKU (Plomin et al., 2013). It was a Norwegian biochemist, Ivar Følling, who in the 1930s discovered that PKU is due to an inability to metabolize the essential amino acid phenylalanine (Følling, 1934). Often parents of children with PKU do not exhibit the condition. Nonetheless, it does run in families and it tends to occur at a higher incidence in small, inbred communities: so that it is sometimes referred to as the Kissing Cousins Disease.

Just like with Mendel's green peas and human blue eyes, PKU is based upon the inheritance of a double dose of recessive alleles (pp). If a parent is homozygous for the

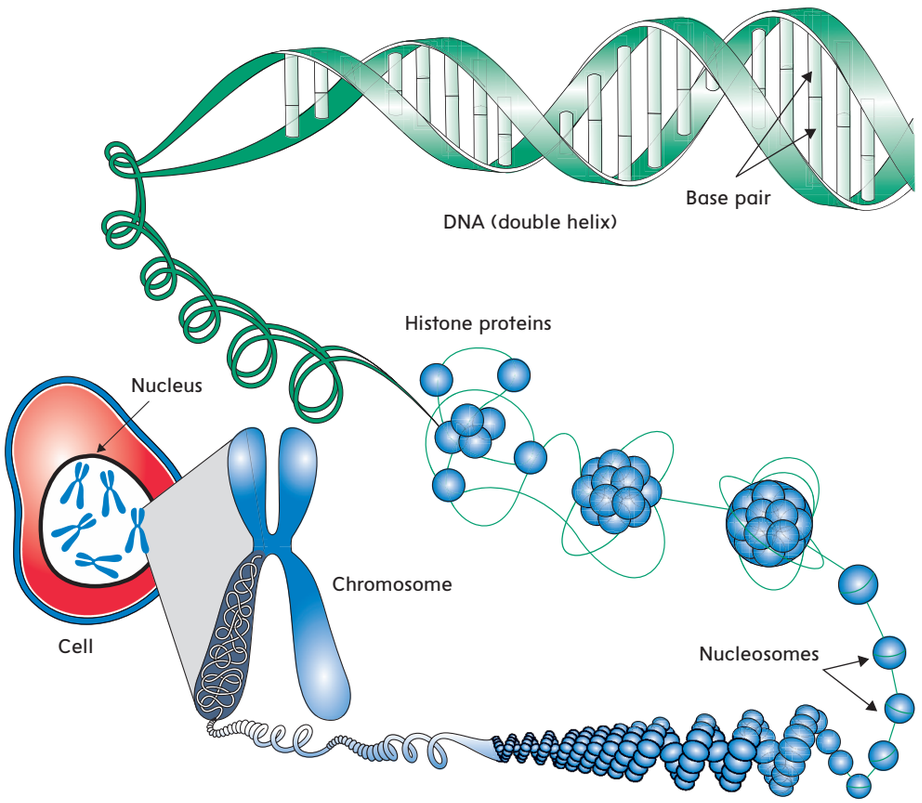

FIGURE 3.7 Chromosomes and DNA.

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dominant allele (PP) he or she cannot pass on the disorder. If one parent is a carrier (Pp) and the other parent is not (PP), then although none of their children will develop the disorder, there is a 50% chance that they will still be a carrier (since they will always receive a dominant allele from the unaffected parent, but have a 50% chance of inheriting a copy of the affected parent's recessive allele). If both parents are carriers, they themselves will not have the disorder, but their offspring will have a 25% chance of inheriting two recessive alleles, one from each parent ($.5 \times .5 = .25$), and if so they will be born with PKU. PKU occurs at a higher rate in small inbred communities because once it develops there is a higher chance of any given individual inheriting the recessive allele and hence a higher chance of them marrying and having children with a fellow carrier. Fortunately, nowadays, there exists a simple urine test for PKU that is routinely administered to newborns and if detected the condition can be treated via diet.

Huntington's Disease

Huntington's disease (HD) is a degenerative disorder in which the sufferer experiences personality changes along with decreasing mental, memory and movement functioning over time. It affects one in 20,000 people. The average age of onset is 40 years. Generally, one parent has the condition and his or her children have a 50% chance of passing it on to their children (Plomin et al., 2013).

HD is based upon the inheritance of a dominant allele; so that the inheritance of the condition is somewhat similar to that found with yellow peas. Unaffected individuals have two recessive alleles, while affected individuals have usually inherited one of the dominant alleles from their affected parent. It would be statistically very unlikely that two heterozygotes (Hh) for HD would meet and have children together. If this ever did occur, then on average each of their children would have a 75% chance of developing the disorder: since there would be a 50% chance of a child being heterozygous for the condition (Hh), a 25% chance of them inheriting a double dose of the dominant allele (HH) so that they and all their future offspring would inherit the condition and a 25% chance of being condition-free having inherited two recessive alleles (hh). HD remains in the population because of its late onset. Since the disorder does not begin to manifest itself until the affected individual is around 40 years of age, by that time he or she will often have had children. Those children will have a 50:50 chance of inheriting the dominant allele from their affected parent and so in turn eventually manifest the symptoms of HD. The Current Topic later in this chapter discusses in depth the emotional and moral quagmire related to genetic screening.

Focus 3.2 Since HD is based upon the inheritance of a dominant allele, why doesn't it slowly increase in the population? For a possible answer conduct a web search using the phrase 'Huntington's Disease and anticipation'.

GENES AND CHROMOSOMES

Although we have talked about genes and their pattern of inheritance a great deal so far, we have not discussed exactly what genes are and what they do. Mendel never actually used the word 'gene'. Instead, he used the phrase 'organic factors', but he had no idea at the molecular level what these factors were or how they worked. Answering these questions is one of the triumphs of twentieth-century science.

So what exactly are genes? **Genes** are functional segments of a long molecule called deoxyribonucleic acid or DNA. Each gene carries the chemical code for manufacturing specific proteins, as well as the codes for when and where in the body they will be made. Proteins can take many forms and functions, and they underlie every bodily structure and chemical process. For that reason, DNA has been described as the blueprint for the body. It used to be thought that humans had a total of around two million genes. However, ever since the mapping of the entire human genome that number has been shrinking. It is now thought that humans have around 20,000 genes (International Genome Sequencing Consortium 2004). The average gene has about 3,000 chemical base pairs, but sizes vary greatly; the largest gene has 2.4 million bases. It is estimated that about half of all genes target brain structure and functions (Kolb & Whishaw, 2003). Every moment of every day, the strands of DNA silently transmit their detailed instructions for cellular functioning.

genes functional segments of the long molecule deoxyribonucleic acid or DNA that code for proteins

DNA is not floating loose in the cell. Instead, it is wound up tightly in tiny rod-like structures called **chromosomes**, which are found only within a cell's nucleus (see Figure 3.7). Chromosomes take the form of a single string or rod (called a chromatid) until they copy themselves just prior to cell division, which is when they assume their iconic X-like shape. Chromosomes are comprised of proteins and DNA. Histone proteins are tiny structures around which the string of DNA is wound rather like thread on a cotton reel. If unravelled, the DNA molecule, although invisible to the naked eye, would be approximately 6 feet or 2 metres long (Masterpasqua, 2009).

Chromosomes come in pairs. All non-sex or **somatic** cells (except for red blood cells that have no nucleus) contain the **diploid** number of chromosomes, which constitutes the full complement with both members of each pair being present. Different species have different diploid numbers of chromosomes: humans have 46 made up of 23 pairs, whereas dogs, for example, have 78 with 39 pairs and fruit flies have 8 with 4 pairs. Sex cells or **gametes** (eggs and sperm) contain what is called the **haploid** number of chromosomes comprised of only one of each of the pairs from one or other of the parents, that is, 23 in humans. When the human egg and sperm combine, the fertilized egg or **zygote** contains all 46 chromosomes, with one of each pair coming from the father and its complementary pair from the mother. The fact that there are complementary pairs of chromosomes relates to alleles. Each gene is represented twice (i.e., as alleles) at the same locus (which is Latin for place; the plural is loci) on each of the chromosome pairs (Figure 3.8).

chromosome a single or double stranded structure comprised of proteins and deoxyribonucleic acid (DNA)

somatic cell is any cell forming the body of an organism. They do not contain reproductive cells

diploid number is a cell consisting of two sets of chromosomes

gametes are sex cells (eggs and sperm)

haploid number is half the number of chromosomes found in a gamete

zygote is a fertilized egg containing 46 pairs of chromosomes

Chromosomes are made of two substances: nucleic acids and proteins. Proteins are much more varied than nucleic acids. They are molecules made of chains of approximately 100 amino acids. The precise order of amino acids along the chain determines the type of protein. There are 20 different kinds of amino acids, thus there are 20^{100} possibly combinations – 20^{100} is more than the total number of atoms in the universe (Patterson, 1998)! Since there are so many potential proteins, initially scientists thought that proteins must contain the heredity code. Instead, the code for life is found in the nucleic acid, DNA.

DNA has a distinctive structure, which was first discovered by Francis Crick and James Watson, largely based upon the experimental work of Maurice Wilkins and Rosalind Franklin, in the early 1950s. Its geometric shape is a double helix, which looks a bit like a twisted ladder. The rails of the ladder are made up of alternating sugar and phosphate molecules. The rungs are made up of pairs of four chemical or nitrogenous bases – adenine (A), thymine (T), guanine (G) and cytosine (C). It is as if the ladder

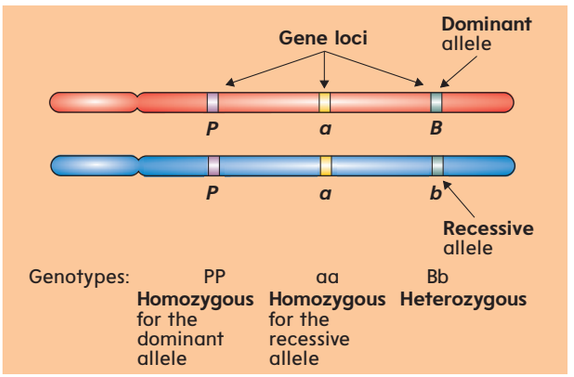

FIGURE 3.8 Alleles and gene loci on a pair of chromosomes.

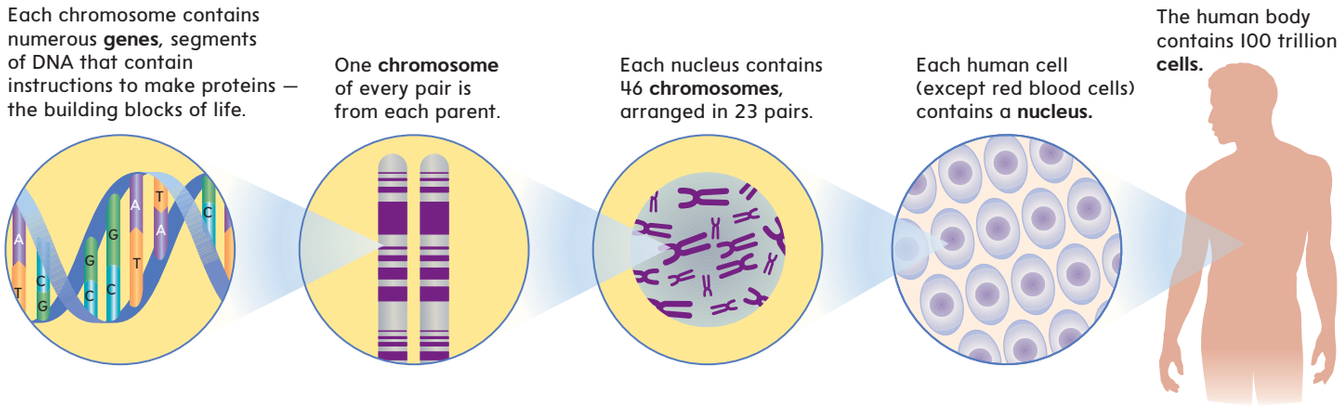

FIGURE 3.9 The ladder of life.

Chromosomes consist of two long, twisted strands of DNA, the chemical that carries genetic information. With the exception of red blood cells, every cell in the body carries within its nucleus 23 pairs of chromosomes, each containing numerous genes that regulate every aspect of cellular functioning.

rungs are made of two halves locked together: the chemical base guanine (G) is always opposite cytosine (C) and adenine (A) is always opposite thymine (T). Figure 3.9 shows a very simplified model of the structure of DNA on the far left.

The beauty of DNA is that it allows for very accurate copying. During replication the two halves of the ladder split lengthways down the centre and each half can be used as a template to reconstruct the whole again. When the ladder is split, free-floating **nucleotides** (which are nitrogenous base, phosphate and sugar groups) in the cell are attracted to their complementary open bases on the DNA strand. It is rather like a self-assembling, four-piece, 3D jigsaw.

nucleotides nitrogenous base, phosphate and sugar groups

codon a non-overlapping triplet sequence of nucleotides

Human DNA has about 3 billion nitrogenous base pairs (Human Genome Project, 2007). The ordering of 99.9% of these bases is the same in all people. The sequence of the four letters of the DNA alphabet – A, T, G and C – creates the specific commands for every feature and function of your body. The basic unit of the genetic code is made up of non-overlapping triplet sequences of nucleotides each of which is called a **codon**. With four different 'letters' (i.e., nitrogenous bases) of the DNA alphabet being read in non-overlapping triplet sequences, there are 64 possible combinations or permutations, 4*4*4 (e.g., AAA, AAT, AAG, AAC, ATA, ATG, ATC etc.). There are two types of statement: one type specifies an amino acid and the other signals 'stop' in the sense that it stops the process of 'translating' a gene. With 20 types of amino acid and a stop sign, the total number of statements needed is 21. With 64 possible permutations, there is a great deal of overlap in the triplet code so that nearly every type of amino acid is specified by more than one codon. For instance, six codons code for the amino acid serine, TCT or TCC or TCA or TCG or AGT or AGT, two codons, TTT or TTC, code for phenylalanine and there are three stop codons, TAG, TGA or TAA (Griffiths, Miller, Suzuki, Lewontin, & Gelbart, 2000).

DNA transcription occurs with the help of another kind of nucleic acid: ribonucleic acid or RNA. RNA has a simpler structure than DNA. It is comprised of a single strand of nucleotides. In addition, instead of the sugar being deoxyribose as it is with DNA, it is ribose in RNA. RNA has the same nitrogenous bases as DNA except that instead of thymine it has uracil.

Transcription begins in the nucleus of the cell. A section of DNA unzips itself exposing the nitrogenous bases of a gene. The nucleotides of messenger RNA (mRNA) are attracted to their complementary bases and they form into a continuous strand along the length of the gene. This strand of mRNA then travels out of the nucleus into the cytoplasm of the cell. A large molecule called a ribose then travels along the length of the mRNA activating

its codons as it goes. When a codon is activated, transfer RNA (tRNA), which is floating loose in the cytoplasm, fixes itself to its complementary codon, rather like a three-pronged key fitting a lock. Specific amino acids are attached to the surface of particular types of tRNA. The amino acids from each tRNA bond together and form a chain. When the ribose reaches the stop codon, the chain of amino acids is released. This chain will fold into a particular shape depending on the order of the different types of amino acids along its length. The shape that the amino acids form determines the specific type of protein they become. Transcription is a very complex process and the description here is extremely simplified. The most important thing to understand is that the end product of genetic transcription is a protein.

Focus 3.3 Although DNA allows for accurate copying, errors do occur. What effect do you think such errors have? Do you think all copying errors will always have bad effects? (As a hint, refer back to the passage on natural selection and mutations. p81–82)

Since genes are primarily code for proteins, it is not technically correct to state that there is a 'gene for' any particular phenotypic feature. Thus phrases such as 'a gene for autism' or 'a gene for eye colour' are technically incorrect. Genes influence phenotypic expression in a more indirect manner. Nonetheless, since proteins are involved in every structure of the body, including the brain, DNA has a profound effect on our cognitive processing, personality and behaviour.

Monogenic and Polygenic Effects

Most of the conditions or traits that we have discussed so far have been monogenic, that is, they are based upon the influence of one gene. However, in a great many instances, a number of gene pairs combine their influences to create a single phenotypic trait. This is known as **polygenic transmission**, and it complicates the straightforward picture that would occur if all characteristics were determined by one pair of genes. It also magnifies the number of possible variations in a trait that can occur. Despite the fact that about 99.9% of human genes are identical among people, it is estimated that the union of sperm and egg can result in about 70 trillion potential genotypes, accounting for the great diversity of characteristics that occurs even among siblings. The majority of traits that are of concern to psychologists such as intelligence and personality are most likely polygenic – assuming that genes influence them at all. Indeed, how do we scientifically establish whether any behavioural traits are under the influence of genes?

polygenic transmission when a number of gene pairs combine their influences to create a single phenotypic trait

In review

- Gregor Mendel showed how inheritance could occur without eliminating biological variation. In elegant breeding experiments with pea plants, he laid down the foundations of genetic science.
- Since Mendel, scientists have uncovered many of the details of the molecular and biochemical processes underlying genetic inheritance. We now know that genes are segments of deoxyribonucleic acid or DNA that encode for particular proteins.
- Some inherited traits are monogenic (based upon the influence of one gene). However, complex traits such as intelligence and personality are most probably polygenic (based upon the influence of many genes). However, all genetically influenced traits interact with environmental influences.

INHERITED BEHAVIOURAL ADAPTATIONS

One way to test whether a behaviour or trait is innate is to deny an organism the opportunity to learn from its environment and test to see if they exhibit the behaviour anyway. It is claimed that in an attempt to learn whether language is an innate ability, James IV of Scotland sent two babies to be raised by a mute woman on the remote island of Inchkeith. It was reported that at the end of the experiment they were found to speak perfect Hebrew (Lindsay, 1814).

Despite James IV's experiment, there is a long history of resistance within psychology to the suggestion that behaviour is based upon innate or inherited predispositions (see **Chapter 1**).

Chapter 1, Page 15

Focus 3.4 Consider the human behaviour of playing badminton. Is it more the results of nature or nurture? Do not forget that one needs to be bipedal, possess good binocular vision and grasping hands to play badminton.

inherited behavioural adaptations traits that organisms are born with that help promote their chances of survival and reproductive success

fixed action pattern (FAP) an unlearned response automatically triggered by a particular stimulus

releasing stimuli external stimuli that trigger fixed action patterns

superstimulus an exaggerated version of a releasing stimulus that triggers a stronger response than the naturalistic model

Behaviourism dominated psychology from the early 1900s through to the 1960s. Behaviourists assumed that there are laws of learning that apply to virtually all organisms. For example, each species they studied – whether birds, reptiles, rats, monkeys or humans – responded in predictable ways to patterns of reward or punishment.

Behaviourists treated the organism as a *tabula rasa*, or 'blank slate', on which learning experiences were inscribed. Most of their research was conducted with non-human species in controlled laboratory settings. Behaviourists explained learning solely in terms of directly observable events and avoided speculating about an organism's mental state (as cognitive psychologists later did).

ETHOLOGY

While behaviourism flourished in early to mid-twentieth-century America, a specialty area called *ethology* arose in Europe within the discipline of biology (Lorenz, 1937; Tinbergen, 1951; Verhulst & Bolhuis, 2009). Ethologists focused on animal behaviour in the natural environment, viewing the organism as much more than a blank slate, and arguing that, because of evolution, every species comes into the world biologically prepared to act in certain ways. Thus, they possess **inherited behavioural adaptations** – traits that they are born with that promote their chances of survival and reproductive success.

An example of the kinds of behaviour studied by ethologists is that of young herring gulls' pecking behaviour. Newly hatched herring gulls beg for food by pecking at a red mark on the lower mandible of their parents' beaks. Parents respond by regurgitating partially digested fish, which the hatchlings ingest. Yet how do the chicks know to do this? Do they peck haphazardly and randomly at first until they by chance strike at the spot on their parent's beak and receive a food reward? If it was found that they did learn this way, it could be explained according to the principles of behaviourism. Yet, Niko Tinbergen suspected that the chicks enter the world with an innate **fixed action pattern** of pecking that could be triggered by pre-programmed **releasing stimuli**. He set out to test his ideas.

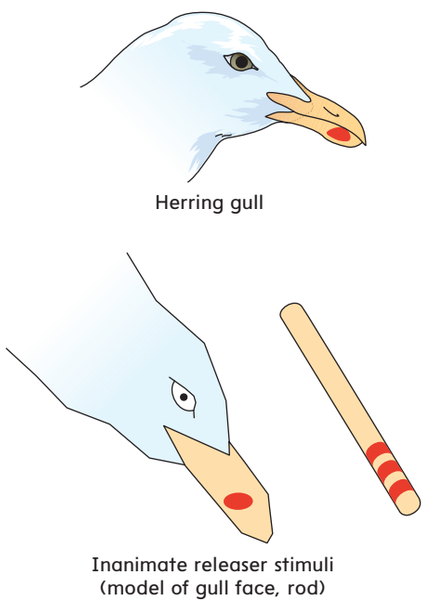

FIGURE 3.10 A herring gull hatchling will peck most frequently at objects that are long and have contrasting foreground and background shades, even if they are inanimate models and do not look like adult gulls. This innate fixed action pattern is present from birth and does not require learning. The stimuli that trigger a fixed action pattern, such as the red markings on the inanimate objects and on the beak of the real herring gull shown here, are called releaser stimuli.

Source: Adapted from Hailman, 1969.

Tinbergen (1950) visited a wild colony of herring gulls and waited for the eggs to hatch. Before the newly hatched chicks had a chance to learn to peck at their parents' beaks, he collected them and presented them with various stimuli to see what would induce them to peck. The chicks did not peck at everything presented to them equally. First, the stimulus had to be moving; and second, it had to have contrasting foreground and background shades. Tinbergen found that the chicks pecked at flat templates cut in the shape of gull heads, as long as they had a distinctive spot at the end of the beak, as much as they pecked at a stuffed natural head. They pecked at black or blue spots as often as red spots. They pecked markedly less at beaks with white spots, no spot or a red spot painted just below the eye. The stimulus they pecked at most, even more than the natural head, was a pointed stick with contrasting red and white horizontal bands painted toward its point (Figure 3.10). Tinbergen called this a **superstimulus** since it worked better than the naturalistic model. Thus it seems that herring gull chicks do enter the world with a predisposition to respond to certain stimuli without needing to rely on learning.

As ethology research proceeded, it became increasingly clear that even quite apparently rigid behaviour such as fixed actions patterns is subject to refinement by learning. For example, Hailman (1967) found that older laughing chicks learn what an adult gull looks like and within a relatively short time of hatching will not peck at an inanimate object unless it resembles the head of an adult gull. Another fascinating example is provided by the migratory behaviour of indigo buntings. The indigo bunting is a songbird that migrates between North and Central America. As if by pure instinct, it knows which direction to fly by using the North Star to navigate. (The North Star is the only stationary star in the Northern Hemisphere that maintains a fixed compass position.) In

autumn, the buntings migrate south by flying away from the North Star; they return in the spring by flying towards it. To study whether any learning was involved in the buntings' navigational behaviour, Emlen (1975) raised birds in a planetarium with either a true sky or a false sky in which a star other than the North Star was the only stationary one. In the autumn, the buntings became restless in their cages as migration time approached. When the birds raised in the planetarium with the true sky were released, they flew away in the direction opposite the North Star. In contrast, those exposed to the false sky ignored the North Star and instead flew away in the direction opposite the 'false' stationary star. Emlen concluded that although the indigo bunting is genetically pre-wired to navigate by a fixed star, it has to learn through experience in the environment which specific star in the night sky is stationary.

Focus 3.5 Do you think yawning is a fixed action pattern (FAP)? What social signal might act as a releasing stimulus for yawning? Why do you think there seem to be few obvious examples of FAPs in humans?

Shared and Unshared Environments

Measuring or estimating the effect of the environment is vital if we are to tease this apart from the effect of genetic influence. Environment is a very broad term, referring to everything from the prenatal world of the womb and the simplest physical environment to the complex social systems in which we interact with multiple people, places and things. Some of these environments, such as our family household or school classroom, are shared with other people, such as our siblings and classmates. This is called a **shared environment** because the people who reside in these experience many of their features in common. Siblings living in the same home are exposed to a common physical environment, the availability or unavailability of books, a television or a computer. They share the quality of food in the home, exposure to the attitudes and values transmitted by parents, and many other experiences. However, each of us also has experiences that are unique to us, or an **unshared environment**. Even children living in the same home have their own unique experiences, including distinct relationships with their parents and siblings.

shared environment the people who reside in these experience many of their features in common

unshared environment experiences that are unique to us

Twin studies (especially those that include twins raised together and apart) are particularly useful in estimating the extent to which genotype, shared environment and unshared environment contribute to group variance on a particular characteristic (see Figure 3.11). As we shall see, such studies have provided new insights on the factors that influence a wide range of human characteristics.

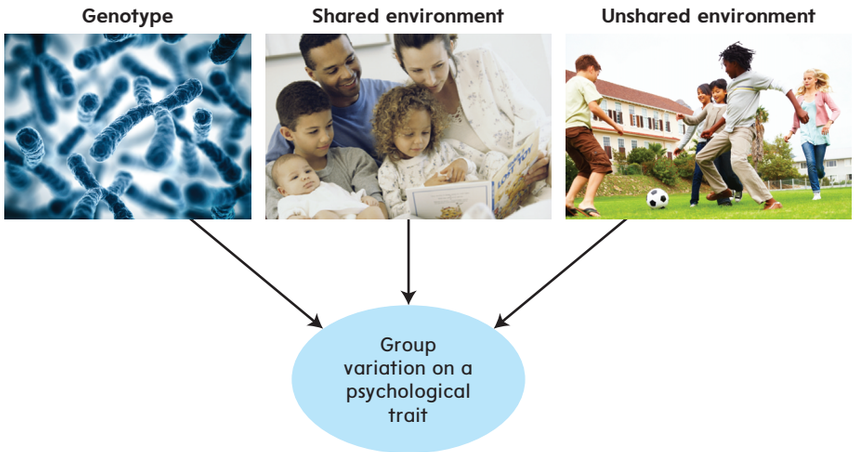

FIGURE 3.11 Behavioural genetics research methods permit the estimation of three sources of variation in a group's scores on any characteristics. It is therefore possible to estimate from results of twin and adoption studies the contributions of genetic factors and of shared and unshared-environmental factors.

Source: (a) ©iStock.com/BlackJack3D; (b) rSnapshotPhotos; (c) ©iStock.com/GlobalStock

In review

- The environment exerts its effects largely through processes of learning that are made possible by innate biological mechanisms. Humans and other organisms can learn which stimuli are important and which responses are likely to result in goal attainment.
- Since learning always occurs within environments, it is important to distinguish between different kinds of environments. Behavioural genetics researchers make an important distinction between shared and unshared environmental influences.

BEHAVIOURAL GENETICS

behavioural genetics how heredity and environmental factors influence psychological characteristics

degree of relatedness the number of genes we share with others by direct common descent

concordance co-occurrence

adoption study people who were adopted early in life are compared on some characteristic both with their biological parents, with whom they share genetic endowment, and with their adoptive parents, with whom they share no genes

Researchers in the field of **behavioural genetics** study how heredity and environmental factors influence psychological characteristics. In contrast to evolutionary psychologists who are interested in the genetic commonalities among people, behavioural geneticists try to determine the relative influence of genetic and environmental factors in accounting for individual differences in behaviour. For example, a behavioural geneticist might ask: 'How important are genetic factors in aggression, intelligence, personality characteristics and various types of psychological disorders?'

Genetic similarity can be expressed in two ways. First, we can take equivalent sections of DNA between different humans or different species and calculate the degree of similarity between base pairs. According to such comparisons, we share around 98–99% of our DNA code with chimpanzees (Venn, Turner, Mathieson, De Groot, Bontrop, & McVean, 2014) and about 99.9% with other unrelated humans. Second, we can express genetic difference in terms of the inheritance of specific alleles from our parents. We directly inherit half our alleles from our mother and the other half from our father. Thus, we receive 50% of each of our parents' genes by direct common descent. The **degree of relatedness** refers to the latter form of genetic comparison. Let's explore the concept of degree of relatedness a little further.

The probability of sharing any particular gene with one of your parents is 50%, or .50. If you have brothers and sisters, you also have a .50 probability of sharing the same gene by common decent with each of them, since they get their genetic material from the same parents. Identical twins share the same genotype (Figure 3.12). Thus, if you are an identical twin, you have a 1.00 probability of sharing any particular gene with your twin. And what about a grandparent? Here, the probability of a shared gene is .25 because, for example, your maternal grandmother passed half of her genes on to your mother, who passed half of hers on to you. Thus the likelihood that you inherited a specific gene from your grandmother is .50 × .50, or .25. The probability of sharing a gene is also .25 for half-siblings, who share half of their genes with the common biological parent but none with the other parent. If you have a first cousin, that is, the daughter or son of your mother's full sister or brother, you share .125 of your genes with him or her. This is because your mother' siblings shares .50 of their genes by common descent with your mother, thus you share .25 with your aunts and uncles and half of that, .125, with their children, your first cousins. An adopted child receives no genes by direct common descent from his or her adoptive parents, and the same is true for unrelated people. These facts about genetic similarity give us a basis for studying the role of genetic factors in physical and behavioural characteristics. If a characteristic has higher **concordance**, or co-occurrence, in people who are more closely related to one another compared to unrelated individuals, this points to a possible genetic contribution, particularly if the people have lived in different environments.

ADOPTION AND TWIN STUDIES

Knowing the degree of relatedness among family and kin provides a basis for estimating the relative contributions of heredity and environment to a physical or psychological characteristic (Kaprio & Silventoinen, 2011). Many studies have shown that the more similar people are genetically, the more similar they are likely to be psychologically, although this level of similarity differs depending on the characteristic in question.

One research method used to estimate the influence of genetic factors is the **adoption study**, in which people who were adopted early in life are compared on some characteristic with both their biological parents, with whom they share genetic endowment, and with their adoptive parents, with whom they share no genes by direct common descent. If adopted people are more similar to a biological parent (with whom they share 50% of their genes) than to an adoptive parent (with whom they share a common environment but no genes), a genetic influence on that trait is indicated. If they are more similar to their adoptive parents, environmental factors are judged to be more important for that particular characteristic.

In one such study, Kety and co-workers (Kety, Rosenthal, Wender, Schulsinger, & Jacobsen, 1978) identified adoptees who were diagnosed with schizophrenia in adulthood. They then examined the backgrounds of the biological and adoptive parents and relatives

to determine the rate of schizophrenia in the two sets of families. The researchers found that 12% of biological family members had also been diagnosed with schizophrenia, compared with a concordance rate of only 3% of adoptive family members, suggesting a hereditary link.

Twin studies, which compare trait similarities in identical and fraternal twins, are one of the more powerful techniques used in behavioural genetics (Boomsma, Busjahn, & Peltonen, 2002). Because *monozygotic*, or identical, twins develop from the same fertilized egg, they are genetically identical (Figure 3.12). Approximately one in 250 births produces identical twins. *Dizygotic*, or fraternal, twins develop from two fertilized eggs, so they share 50% of their genetic endowment, like any other set of brothers and sisters. Approximately one in 150 births produces fraternal twins.

twin studies compare trait similarities in identical and fraternal twins

concordance rates statistical expression of the probability that two individuals with shared genes will share a particular trait to the same degree

Twins, like other siblings, are usually raised in the same familial environment. Thus, we can compare **concordance rates**, or trait similarity, in samples of identical and fraternal twins. We assume that if the identical twins are far more similar to one another than are the fraternal twins in a specific characteristic, a genetic factor is likely to be involved. Of course, the drawback is the possibility that because identical twins are more similar to one another in appearance than fraternal twins are, they are treated more alike and therefore share a more similar environment. This could partially account for greater behavioural similarity in identical twins.

To rule out this environmental explanation, behavioural geneticists have adopted an even more elegant research method. Sometimes researchers are able to find and compare sets of identical and fraternal twins who were separated very early in life and raised in *different* environments (Bouchard et al., 1990). By eliminating environmental similarity, this research design permits a better basis for evaluating the respective contributions of genes and environment.

Some of the similarities found between identical twins raised apart from infancy and reunited in adulthood are extraordinary. For example, Jim Lewis and Jim Springer first met in 1979 after 39 years of being separated. They had grown into adulthood oblivious to the existence of one another until Jim Lewis felt a need to learn more about his family of origin. When they met, Lewis described it as 'like looking into a mirror', but the similarities went far beyond their nearly identical appearance. Despite having been raised apart, they discovered that they shared some very surprising similarities. They both had childhood dogs named Toy. Both had been nail-biters and fretful sleepers, suffered from migraine headaches and had high blood-pressure. Both men married women named Linda, had been divorced and married second wives named Betty. Lewis named his first son James Allen, Springer named his James Alan. For years, they both had taken holidays at the same Florida beach. Both of the Jims worked as sheriff's deputies. They both drank the same kind of beer and smoked the same brand of cigarettes. Both loved and hated the same sports and left regular love notes to their wives, made doll's furniture in their basements, and had constructed unusual circular benches around the trees in their gardens (see Figure 3.13).

Focus 3.6 Why are adoption and twin studies so useful when trying to estimate genetic and environmental influences upon behaviour?

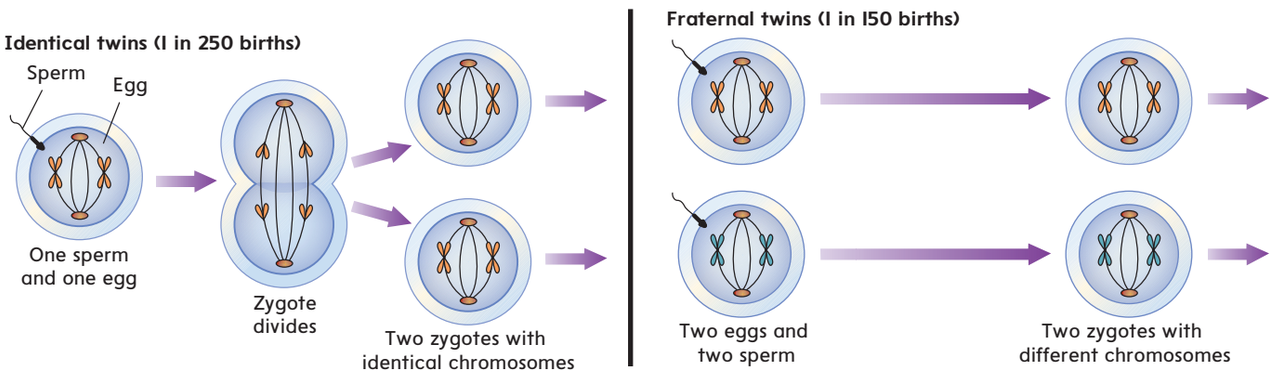

FIGURE 3.12 Genetics of twins.

Identical (monozygotic) twins come from a single egg and sperm as a result of a division of the zygote. They have all of their genes in common. Fraternal (dizygotic) twins result from two eggs fertilized by two sperm. They share only half of their genes as a result.

(a) (b)

FIGURE 3.13 Jim Springer and Jim Lewis are identical twins who were separated when four weeks old and raised in different families. When reunited in adulthood, they showed striking similarities in personality, interests and behaviour.

Source: Michael Nichols/National Geographic Creative/National Geographic

Many of the similarities found between the Jim twins and others like them are no doubt due to coincidence. Nonetheless, as we shall see, many (but not all) psychological characteristics, including intelligence, personality traits and certain psychological disorders, have a notable genetic contribution (Bouchard, 2004). Adopted children are typically found to be more similar to their biological parents than to their adoptive parents on these measures, and identical twins tend to be more similar to one another than are fraternal twins, even if they were separated early in life and reared in different environments (Loehlin, 1992; Lykken, McGue, Tellegen, & Bouchard, 1992; Plomin & Spinath, 2004). On the other hand, identical twins reared together still tend to be somewhat more similar for some characteristics than those reared apart, indicating that the environment also makes a difference.

Heritability: Estimating Genetic Influence

Using adoption and twin studies, researchers can apply a number of complex statistical techniques to estimate the extent to which differences among people are due to genetic differences. A **heritability coefficient** estimates the extent to which the differences, or variation, in a specific phenotypic characteristic within a specific group of people tested can be attributed to their differing genes. For example, the figure for weight found by Bouchard et al. (1990) in their sample of Minnesota Twins was relatively high, at around 60%. It is important that you understand what this .60 heritability coefficient does *not* mean. This result does not mean that the probability that a person will be a particular weight is 60% due to genetic factors and 40% due to the environment. Heritability applies only to differences *within the particular group tested* and estimates can and do vary, depending on the group.

heritability coefficient estimates the extent to which the differences, or variation, in a specific phenotypic characteristic within a group of people can be attributed to their differing genes

Focus 3.7 Define heritability. How are heritability coefficients estimated?

Table 3.1 shows the wide range of heritability that has been found for a range of physical and psychological characteristics. Subtracting each heritability coefficient from 1 provides an estimate of the proportion of variability in the particular group tested that is attributable to the environment in which they developed. For height, environment accounts for only about 1 minus .9, a proportion of .1 (or 10%), of the variation within the group, but for individual difference in preferred characteristics in a mate, environment accounts for virtually all differences among the people tested.

TABLE 3.1 Heritability estimates for various human characteristics

Trait	Heritability estimate
Height	.80
Weight	.60
Likelihood of being divorced	.50
School achievement	.40
Activity level	.40
Preferred characteristics in a mate	.10

Source: Bouchard et al., 1990; Dunn & Plomin, 1990.

Even while they try to estimate the contributions of genetic factors, behavioural geneticists realize that genes and environment are not really separate determinants of behaviour. Instead, they operate as a single, integrated system. Gene expression is influenced on a daily basis by the environment. For example, two children of equal intellectual potential may have differences in intelligence quotients (IQs) as great as 15 to 20 points if one is raised in an impoverished environment and the other in an enriched environment (Plomin & Spinath, 2004).

And high or low environmental stress can be responsible for turning on or off genes that regulate the production of stress hormones (Taylor, 2006a). The genetic influence on certain psychological disorders can be very significant indeed (Neumeister et al., 2004), including a disposition for schizophrenia (Kleinman et al., 2011) and autistic spectrum disorders (**Chapter 17**) (Miles, 2011). It is our genetics that provide some of us with a predisposition to suffer with a problem. This is certainly true of depression (Mickey et al., 2011). Weissman et al. (1984) showed that having relatives that have suffered from depression before the age of 20 means that you are significantly (eight times) more likely to suffer yourself at some point in your life. Of course, as we see elsewhere in the book, a predisposition (or diathesis) to suffer with something does not mean that you certainly will, just that it may happen given the correct experiences, and environment.

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Caspi et al. (2002) looked at how the environment and genetics interacted. The gene they were interested in was the MAOA gene, which they thought may relate to violent or aggressive behaviour. They genotyped a number of men from New Zealand. The reason they did this was that there had been previous evidence of violent behaviour in a Dutch family who had an MAOA mutation, so looking specifically at this gene made sense. The results were very interesting. They showed that the MAOA genotype did not, in itself, correlate with violent activity, but if low MAOA activity was coupled with a history of child abuse while younger, then the men were four times more likely to be convicted of a violent crime before the age of 24: clear evidence of nature (genetics) and nurture (the environment) interacting.

Of the many psychological characteristics that we possess, few if any are more central to our personal identity and our successful adaptation than intelligence and personality. Although we consider these topics in much greater detail in Chapters 10 and 15, respectively, intelligence and personality are particularly relevant to our current discussion because the genetic and environmental factors that influence them have been the subject of considerable research.

GENES, ENVIRONMENT AND INTELLIGENCE

To what extent are differences in intelligence (as defined by an IQ score derived from a general intelligence test) due to genetic factors? This seemingly simple question has long been a source of controversy and, at times, bitter debate. The answer has important social as well as scientific consequences.

Heritability of Intelligence

Let us examine the genetic argument. Suppose that intelligence were totally heritable, that is, suppose that 100% of the intellectual variation in the population were determined by genes. (No psychologist today would maintain that this is so, but examining the extreme view can be instructive.) In that case, any two individuals with the same genotype would have identical intelligence test scores, so the correlation in IQ between identical (monozygotic) twins would be 1.00. Non-identical brothers and sisters (including fraternal twins, who result from two fertilized eggs) share only half of their genes. Therefore, the correlation between the test scores of fraternal twins and other siblings should be substantially lower. Extending the argument, the correlation between a parent's test scores and his or her children's scores should be about the same as that between siblings, because a child inherits only half of his or her genes from each parent.

What do the actual data look like? Table 3.2 summarizes the results from many studies. As you can see, the correlation between the test scores of identical twins is substantially higher than any other correlations in the table (but they are not 1.00). Identical twins separated early in life and reared apart are of special interest because they have identical genes but experienced different environments. Note that the correlation for identical twins raised apart is nearly as high as that for identical twins reared together. It is also higher than that for fraternal twins raised together. This pattern of findings is a powerful argument for the importance of genetic factors (Bouchard et al., 1990; Plomin, DeFries, & Fulker, 2007).

TABLE 3.2 Correlations in intelligence among people who differ in genetic similarity and who live together or apart

Relationship	Percentage of shared genes	Correlation of IQ scores
Identical twins reared together	100	.86
Identical twins reared apart	100	.75
Non-identical twins reared together	50	.57
Siblings reared together	50	.45
Siblings reared apart	50	.21
Biological parent – offspring reared by parent	50	.36
Biological parent – offspring not reared by parent	50	.20
Cousins	25	.25
Adopted child – adoptive parent	0	.19
Adopted children reared together	0	.32

Sources: Based on Bouchard & McGue, 1981; Bouchard et al., 1990; Scarr, 1992.

Focus 3.8 How large a factor is heritability in individual differences in intelligence?

Adoption studies are also instructive. As Table 3.2 shows, IQs of adopted children correlate as highly with their biological parents' IQs as they do with the IQs of the adoptive parents who reared them. Overall, the pattern is quite clear: the more genes people have in common, the more similar their IQs tend to be. This is very strong evidence that genes play a significant role in intelligence, accounting for 50 to 70% of group variation in IQ (Petrill, 2003; Plomin & Spinath, 2004). However, analysis of the human genome shows that there clearly is not a single 'intelligence' gene (Plomin & Craig, 2002). The diverse abilities measured by intelligence tests are undoubtedly influenced by large numbers of interacting genes, and different combinations seem to underlie specific abilities (Luciano, Wright, Smith, Geffen, Geffen, & Martin, 2001; Plomin & Spinath, 2004).

Environmental Determinants

Because genotype accounts for only 50 to 70% of the IQ variation among the individuals in these studies, genetics research provides a strong argument for the contribution of environmental factors to intelligence (Plomin & Spinath, 2004). Good places to look for such factors are in the home and school environments.

Shared family environment

How important to intelligence level is the shared environment of the home in which people are raised? If home environment is an important determinant of intelligence, then children who grow up together should be more similar than children who are reared apart. As Table 3.2 shows, siblings who were raised together were indeed more similar to one another than those reared apart, whether they were identical twins or biological siblings. Note also that there was a correlation of .32 between unrelated adopted children reared in the same home. Overall, it appears that between a quarter and a third of the individual differences in intelligence found in these particular groups could be attributed to shared-environmental factors.

The home environment clearly matters, but there may be an important additional factor. Recent research suggests that differences within home environments are much more important at lower socioeconomic levels than they are in upper-class families. This may be because lower socioeconomic families differ more among themselves in the intellectual richness of the home environment than do upper-class families (Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003). Indeed, a lower-income family that has books in the house, cannot afford video games and encourages academic effort may be a very good environment for a child with good intellectual potential.

Environmental enrichment and deprivation

Another line of evidence for environmental effects comes from studies of children who are removed from deprived environments and placed in middle- or upper-class adoptive

homes. Typically, such children show a gradual increase in IQ in the order of 10 to 12 points (Scarr & Weinberg, 1977; Schiff & Lewontin, 1986). Conversely, when deprived children remain in their impoverished environments, they either show no improvement in IQ or they actually deteriorate intellectually over time (Serpell, 2000). Scores on general intelligence tests correlate around .40 with the socioeconomic status of the family in which a child is reared (Lubinski, 2004).

Educational experiences

As we might expect, educational experiences, perhaps best viewed as a non-shared variable, can also have a significant impact on intelligence. Many studies have shown that school attendance can raise IQ and that lack of attendance can lower it. A small decrease in IQ occurs over summer holidays, especially among low-income children. Intelligence quotient scores also drop when children are unable to start school on time owing to teacher shortages or strikes, natural disasters, or other reasons (Ceci & Williams, 1997). It appears that exposure to an environment in which children have the opportunity to practise mental skills is important in solidifying those skills.

Focus 3.9 Describe the shared and unshared environmental influences on intelligence.

Where intelligence is concerned, we have seen that genetic factors, shared environment and unique experiences all contribute to individual differences in intelligence. Do the same factors apply to personality differences?

GENES, ENVIRONMENT AND PERSONALITY

'Like father, like son' is a saying which young and even quite old men hear very often. But if this old saying has validity, what causes similarities in personality between fathers and sons (and mothers and daughters)? Is it genes, environment, or both?

Heritability of Personality

Behavioural genetics studies on personality have examined genetic and environmental influences on relatively broad personality traits (e.g., Schermer, Vernon, Maio, & Jany, 2011). One prominent personality trait theory is called the five factor model (see **Chapter 15**). Five factor theorists believe that individual differences in personality can be accounted for by variation along five broad personality dimensions or traits known as the Big Five: (1) *extraversion–introversion* (sociable, outgoing, adventuresome, spontaneous versus quiet, aloof, inhibited, solitary); (2) *agreeableness* (cooperative, helpful, good natured versus antagonistic, uncooperative, suspicious); (3) *conscientiousness* (responsible, goal-directed, dependable versus undependable, careless, irresponsible); (4) *neuroticism* (worrying, anxious, emotionally unstable versus well adjusted, secure, calm); and (5) *openness to experience* (imaginative, artistically sensitive, refined versus unreflective, crude and boorish, lacking in intellectual curiosity) (McCrae & Costa, 2003).

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What results are obtained if we compare the Big Five traits in identical and fraternal twins who were raised together and those who were raised apart? Table 3.3 shows heritability estimates of the Big Five personality factors described above. These results are consistent with studies of other personality variables as well, indicating that between 40 and 50% of the personality variations among people included in these studies are attributable to genotype differences (Bouchard, 2004). Although personality characteristics do not show as high a level of heritability as the .70 figure found for intelligence, it is clear that genetic factors account for a significant amount of personality difference.

TABLE 3.3 Heritability of the big five personality factors based on twins studies

Trait	Heritability coefficient
Extraversion	.54
Neuroticism	.48
Conscientiousness	.49
Agreeableness	.42
Openness to experience	.57

Source: Bouchard, 2004.

Environment and Personality Development

If genetic differences in previous twins studies account for only about 40 to 50% of variations in personality (Bouchard, 2004), then surely environment is even more important than it is in the case of intelligence. Researchers expected that the shared environment might be even more important for personality than it is for intelligence. Over the years, virtually every theory of personality has embraced the

assumption that experiences within the family, such as the amount of love expressed by parents and other child-rearing practices, are critical determinants of personality development. Imagine, therefore, the shock waves generated by the findings from twin studies that shared features of the family environment account for little or no variance in major personality traits (Bouchard, Guillemette, & Landry-Léger, 2004; Plomin, 1997). The key finding was that twins raised together and apart, whether identical or fraternal, did not differ in their degree of personality similarity (although identical twins were always more similar to one another than were fraternal twins). In fact, researchers have found that pairs of children who are raised within the same family are as different from one another as are pairs of children who are randomly selected from the population (Plomin & Caspi, 1999).

Adoption studies support a similar conclusion. In adoption studies, the average correlation for personality variables between adopted siblings who are genetically dissimilar but do share much of their environment, including the parents who raise them, the schools they attend, the religious training they receive, and so on, is close to .00 (Plomin, Fulker, Corley, & DeFries, 1997). Except at child-rearing extremes, where children are abused or seriously neglected, parents probably get more credit when children turn out well personality-wise – and more blame when they do not – than they deserve (Scarr, 1992).

Focus 3.10 Since research has indicated that environment makes little contribution to individual differences in personality development, should parents not bother to try and influence their children's manners and morals?

However, the surprising findings concerning shared environments do not mean that experience is not important. Rather than the general family environment, it seems to be the individual's unique or unshared environment, such as his or her unique school experiences (for example, being in Mr Jones's classroom, where conscientiousness and openness to experience were stressed) and interactions with specific peers (such as Jeremy, who fostered extraverted relationships with others) that account for considerable personality variance. Even within the same family, we should realize, siblings have different experiences while growing up, and each child's relationship with his or her parents and siblings may vary in important ways. It is these unique experiences that help shape personality development. Whereas behavioural geneticists have found important shared-environment effects in intelligence, attitudes, religious beliefs, occupational preferences, notions of masculinity and femininity, political attitudes, and health behaviours such as smoking and drinking (Larsen & Buss, 2007), these shared-environment effects do not extend to general personality traits such as the Big Five. At this point, we do not know whether there are some crucial unshared-environmental variables that researchers have missed because of their preoccupation with shared-environmental factors, or whether there are countless small variables that make the difference. This question is of key importance to personality research.

In review

- Hereditary potential is carried in the genes, whose commands trigger the production of proteins that control body structures and processes. Genotype (genetic structure) and phenotype (outward appearance) are not identical, in part because some genes are dominant while others are recessive. Many characteristics are polygenic in origin, that is, they are influenced by the interactions of multiple genes.
- Behavioural geneticists study how genetic and environmental factors contribute to the development of psychological traits and behaviours. Adoption and twin studies are the major research methods used to disentangle hereditary and environmental factors. Especially useful is the study of identical and fraternal twins who were separated early in life and raised in different environments. Identical twins are more similar on a host of psychological characteristics, even when reared apart. Many psychological characteristics have appreciable heritability.
- Intelligence has a strong genetic basis, with heritability coefficients in the .50 to .70 range. Shared family environment is also important (particularly at lower socio-economic levels), as are educational experiences.
- Personality also has a genetic contribution, though not as strong as that for intelligence. In contrast to intelligence, shared family environment seems to have no impact on the development of personality traits. Unshared individual experiences are far more important environmental determinants.

GENE–ENVIRONMENT INTERACTIONS

Genes and environment both influence intelligence, personality and other human characteristics. But, as we have stressed throughout this chapter, they rarely operate independently. Even the prenatal environment can influence how genes express themselves, as when the mother's drug use or malnutrition retards gene-directed brain development. In the critical periods following birth, enriched environments, including the simple touching or massaging of newborns, can influence the unfolding development of premature infants (Field, 2001) and the future 'personality' of young monkeys (Harlow, 1958). Although they cannot modify the genotype itself, environmental conditions can influence how genetically based characteristics express themselves phenotypically throughout the course of development (Plomin et al., 2007).

Just as environmental effects influence phenotypic characteristics, genes can influence how the individual will experience the environment and respond to it (Hernandez & Blazer, 2007; Plomin & Spinath, 2004). Let us examine some of these interactions between genes and experience.

reaction range the range of possibilities – the upper and lower limits – that the genetic code allows

HOW THE ENVIRONMENT CAN INFLUENCE GENE EXPRESSION

First, genes produce a range of potential outcomes. The concept of *reaction range* provides one useful framework for understanding gene–environmental interactions. The **reaction range** for a genetically influenced trait is the range of possibilities – the upper and lower limits – that the genetic code allows. For example, to say that intelligence is genetically influenced does not mean that intelligence is fixed at birth. Instead, it means that an individual inherits a *range* for potential intelligence that has upper and lower limits. Environmental effects will then determine where the person falls within these genetically determined boundaries.

At present, genetic reaction ranges cannot be measured directly, and we do not know if their sizes differ from one person to another. The concept has been applied most often in the study of intelligence. There, studies of IQ gains associated with environmental enrichment and adoption programmes suggest that the ranges could be as large as 15 to 20 points on the IQ scale (Dunn & Plomin, 1990). If this is indeed the case, then the influence of environmental factors on intelligence would be highly significant. A shift this large can move an individual from a below-average to an average intellectual level, or from an average IQ that would not predict college success to an above-average one that would predict success.

Some practical implications of the reaction range concept are illustrated in Figure 3.14. First, consider persons B and H. They have identical reaction ranges, but person B develops in a very deprived environment and H in an enriched environment with many cultural and educational advantages. Person H is able to realize her innate potential and has an IQ that is 20 points higher than person B's. Now compare persons C and I. Person C actually has greater intellectual potential than person I but ends up with a lower IQ as a result of living in an environment that does not allow that potential to develop. Finally, note person G, who was born with high genetic endowment and reared in an enriched environment. His slightly above-average IQ of 110 is lower than we would expect, suggesting that he did not take advantage of either his biological capacity or his environmental advantages. This serves to remind us that intellectual growth depends not only on genetic endowment and environmental advantage, but also on interests,

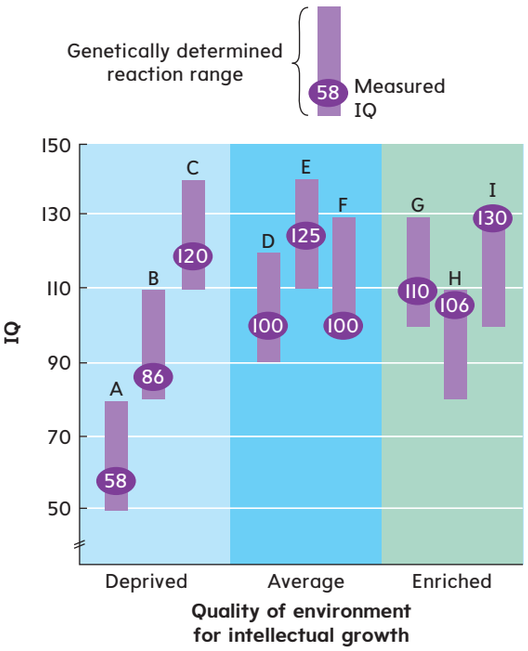


FIGURE 3.14 Reaction range is an example of how environmental factors can influence the phenotypic expression of genetic factors. Genetic endowment is believed to create a range of possibilities within which environment exerts its effects. Enriched environments are expected to allow a person's intelligence to develop to the upper region of his or her reaction range, whereas deprived environments may limit intelligence to the lower portion of the range. Where intelligence is concerned, the reaction range may cover as much as 15 to 20 points on the IQ scale.

motivation and other personal characteristics that affect how much we apply ourselves or take advantage of our gifts and opportunities.

As noted earlier, heritability estimates are not universal by any means. They can vary, depending on the sample being studied, and they may be influenced by environmental factors. This fact was brought home forcefully in research by Turkheimer and colleagues (2003). They found in a study of seven-year-old identical and fraternal twins that the proportions of IQ variation attributable to genes and environment varied by social class. In impoverished families, fully 60% of the IQ variance was accounted for by the shared (family) environment, and the contribution of genes was negligible. In affluent families, the result was almost the reverse, with shared environment accounting for little variance and genes playing an important role. Clearly, genes and social-class environment seem to be interacting in their contribution to IQ.

Focus 3.II Describe reaction range and its hypothesized effects on the genetic expression of intelligence.

It seems quite likely that there are genetically based reaction ranges for personality factors as well. This would mean that, personality-wise, there are biological limits to how malleable, or changeable, a person is in response to environmental factors. However, this hardly means that biology is destiny. Depending on the size of reaction ranges for particular personality characteristics – and even, perhaps, for different people – individuals could be quite susceptible to the impact of unshared environmental experiences.

HOW GENES CAN INFLUENCE THE ENVIRONMENT

Reaction range is a special example of how environment can affect the expression of genetically influenced traits. But there are other ways in which genetic and environmental factors can interact with one another. Figure 3.15 shows three ways in which genotype can influence the environment, which, in turn, can influence the development of personal characteristics (Scarr & McCartney, 1983).

First, genetically based characteristics may influence aspects of the environment to which the child is exposed. For example, we know that intelligence has strong heritability. Thus, a child born to highly intelligent parents is also likely to have good intellectual potential. If, because of their own interests in intellectual pursuits, these parents provide an intellectually stimulating environment with lots of books, educational toys, computers, and so on, this environment may help foster the development of mental skills that fall at the top of the child's reaction range. The resulting bright child is thus a product both of the genes shared with the parents and of his or her ability to profit from the environment they provide.

evocative influence a child's genetically influenced behaviours may evoke certain responses from others

A second genetic influence on the environment is called the **evocative influence**, meaning that a child's genetically influenced behaviours may evoke certain responses from others. For example, some children are very cuddly, sociable and outgoing almost from birth, whereas others are more aloof, shy and do not like to be touched or approached. These characteristics are in part genetically based (Kagan, 1999; Plomin et al., 2007). Think of how you yourself would be most likely to respond to these two types of babies. The outgoing children are likely to be cuddled by their parents and evoke lots of friendly responses from others as they mature, creating an environment that supports and strengthens their sociable and extraverted tendencies. In contrast, shy, aloof children typically evoke less positive reactions from others, and this self-created environment may strengthen their genotypically influenced tendency to withdraw from social contact.

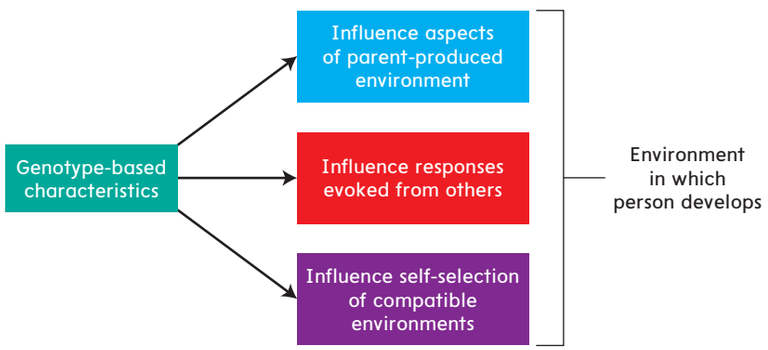


FIGURE 3.15 Three ways in which a person's genotype can influence the nature of the environment in which the person develops.

Source: Based on Scarr and McCartney, 1983.

In both of these examples, genotype helped create an environment that reinforces already existing biologically based tendencies. However, a behaviour pattern can also evoke an environment that counteracts the genetically

favoured trait and discourages its expression. We know, for example, that activity level has moderate heritability of around .40 (Table 3.1). Thus, parents of highly active 'off the wall' children may try to get them to sit still and calm down, or those of inactive children may press the child into lots of physical activities designed to increase physical well-being, in both instances opposing the natural tendencies of the children. Thus, the environment may either support or discourage the expression of a person's genotype.

Finally, people are not simply passive responders to whatever environment happens to come their way. We actively seek out certain environments and avoid others. Genetically based traits may therefore affect the environments that we select, and these environments are likely to be compatible with our traits. Thus, a large, aggressive boy may be attracted to competitive sports with lots of physical contact, a highly intelligent child will seek out intellectually stimulating environments, and a shy, introverted child may shun social events and prefer solitary activities or a small number of friends. These varied self-selected environments may have very different effects on subsequent development. We therefore see that how people develop is influenced by both biology and experience, and that these factors combine in ways that are just beginning to be understood.

Focus 3.12 Describe three ways that genotype can affect environmental influences on behaviour.

In review

- Genetic and environmental factors rarely operate alone; they interact with one another in important ways. Genetic factors may influence how different people experience the same environment, and the environment can influence how genes express themselves.
- Genetic factors can influence the environment in three important ways. First, genes shared by parents and children may be expressed in the parents' behaviours and the environment they create. Second, genes may produce characteristics that influence responses evoked from others. Finally, people may self-select or create environments that are consistent with their genetic characteristics.

GENETIC MANIPULATION AND CONTROL

Until recently, genetics researchers had to be content with studying genetic phenomena occurring in nature. Aside from selectively breeding plants and animals for certain characteristics or studying the effects of genetic mutations, they had no ability to influence genes directly. Today, however, technological advances have enabled scientists not only to map the human genome but also to duplicate and modify the structures of genes themselves (Aldridge, 1998).

EPIGENETICS

Epigenetics, or 'alterations in the phenotype or gene expression due to mechanisms other than changes in the underlying DNA sequence' (Archer, Beninger, Palomo, & Kostrzewa, 2010, p. 347) is an emerging area of research. Put more simply, it is the study of changes in the gene expression that are independent of the DNA itself, caused instead by environmental factors (Allis, 2009). This area of research opens up a brave new world where, not content with looking at naturally occurring genetic phenomena, scientists can now directly influence, manipulate and duplicate the structure of the genes themselves. Of course, natural expressions and manipulations have been carried out for centuries, notably by Mendel and animal breeders, but epigenetics opens up a door to an as yet unthinkable level of flexibility regarding genetic expressions.

epigenetics study of changes in gene expression due to environmental factors and independent of the DNA

In some cases, genes from one species may be spliced into the DNA of a similar, closely related species. It is well known that we humans differ only slightly in genetic code from quite different animals and (although the small difference is a very important one indeed)

we share a number of similarities – eyes for instance. The *Pax6* gene has been identified as responsible for eye development. If this gene is not switched on at the correct time, eyes do not develop. If the human *Pax6* gene is inserted into the side of the fruit fly an eye does indeed develop there, but not a human eye. Instead, a multifaceted, drosphylia eye, appropriate to the fly in which the gene was implanted develops. This, says Hartwell, Hood, Goldberg, Reynolds and Silver (2010) is an example of the importance of the biological environment in which the gene resides. It is not, then, only the DNA itself that is vital in the expression of the gene. Masterpasqua (2009) says that the physical environment in which the gene resides, as well as the social environment of the host, can be influential in changing molecular structures that are themselves responsible for regulating gene expression.

Gene-manipulation can be achieved in a number of ways. For instance, therapies can be developed to modify the structure of brain tissue. To do this, you first need to find a virus that can travel into the brain. Next you need to modify the genetic code of the virus before it is released into the host. Enzymes are used that can split threads of the DNA to be inserted into pieces, before combining it with the DNA of the virus, which then carries the inserted DNA to the brain. Similarly, the DNA of bacterium can be modified with pieces of DNA so that when inserted into a host the new bacterium subdivides to produce multiple copies of itself, spreading the DNA throughout the host.

knock-out procedure where a function of a gene is removed, or eliminated

knock-in procedure where a new gene is inserted into an animal at embryonic stage

Knock-Out and Knock-In Procedures

These are two methods of genetic modification, typically, and currently carried out in mice. In each case a component of the DNA is either removed (**knock-out procedure**) or new genetic material is inserted (**knock-in procedure**). In each case, a function of the gene is either removed or another function is inserted.

Current topic

TO KNOW OR NOT TO KNOW – GENETIC SCREENING

Our knowledge of human DNA and screening programmes to identify whether people may be susceptible to genetic diseases has already improved the amelioration of symptoms and improved the quality of life of a good many people through tests that help with diagnosis and targeted treatment. Genetic screening can also be used in identifying genetic illnesses in embryos, and so gives parents a choice whether to bring a child with a genetic problem into the world. This side of the debate, the protesting side, is very clear. Knowing you have or may contract a disease is vital in its treatment, or in avoiding environmental stimuli that may cause difficulties. Similarly, knowing that a disease may be contracted may allow a person to take protective steps by modifying their own behaviour. Where muscles or muscular control may be influenced by an illness for instance, the person may take time over a fitness programme specifically designed to target and strengthen areas of their body that may be affected by the disease, thereby improving their ability to deal with the symptoms.

Genetic testing of embryos typifies a very clear problem with this sort of therapy, and provokes a heated and emotional debate. Ethically, identifying a genetic illness can be extremely problematic. Some would argue that a life, be it one with issues relating to a genetic illness, is still a life and screening like this is something we should not be doing, Also of interest to those of this opinion would be that tests can sometimes give false results. Additionally, knowing that you might contract Alzheimer's or Huntington's disease is not the same as contracting it. Similarly, genetic modifications may in the future allow us to combat psychological problems such as schizophrenia or depression. It should be recognized, however, that environmental factors play a role and these should not be ignored. The psychological issues of knowing that you may contract a particular illness should not be underestimated. The character 'Thirteen' from the television series *House*, did all she could to avoid finding out whether she carried the gene for Huntington's disease, that killed the pioneering folk singer Woody Guthrie in 1967 (Figure 3.16). Many would say that knowing is best, but a similar number would not want to know the illness that may carry them off. The moral debates surrounding gene therapy look set to continue. No one can deny, however, that epigenetics looks set to play a very important role in all our futures.

To inform your debate, consider the following points where we summarize again a few of the more pertinent and controversial areas for discussion.

To summarize, three questions are important in thinking about genetic screening:

1. *What are the potential benefits of genetic screening*? There are at present more than 900 genetic tests available from testing laboratories (Human Genome Project, 2007). Proponents argue that screening can provide information that will benefit people. Early detection of a treatable condition can save lives. For example, were you to find through genetic screening that you have a predisposition to develop heart disease, you could alter your lifestyle with exercise and dietary measures to improve your chances of staying healthy. Screening could also affect reproductive decisions that reduce the probability of having children affected by a genetic disease. In a New York community, Hasidic Jews from Eastern Europe had a high incidence of Tay-Sachs disease, a fatal, genetically based neurological disorder. A genetic screening programme allowed rabbis to counsel against child-bearing in marriages involving two carriers of the abnormal allele, virtually eliminating the disease in offspring.
2. *How accurate are the screens?* Another issue is whether an inaccurate screen may result in fateful decisions. Although screens for various diseases exceed 90% accuracy, it is still possible that there can be a false positive result (an indication that a genetic predisposition to a disorder is present when it is not). Thus, a person may decide not to have children on the basis of an erroneous test that indicates a high risk of having a child with a particular problem. Alternatively, a false negative test may indicate that a predisposition is not present when in fact it is. Moreover, some tests, called *susceptibility tests*, simply tell you that you are more likely than others to develop a particular disorder, with no assurance that that will indeed occur.
3. *How should people be educated and counselled about test results?* Because of the importance of decisions that might be made on the basis of genetic screening, there is strong agreement that clients should be educated and counselled by specially trained counsellors. In the sickle-cell anaemia screening of the 1970s, follow-up education was inadequate, the result being that some African-American men who were informed that they were carriers of the sickle-cell allele elected to remain childless because they were not told that the disorder would not occur in their offspring if their mates were non-carriers of the allele. The genetic counsellor's role is to help the person, couple or family to decide whether to be screened, to help them to fully understand the meaning of the test results, and to assist them during what might well be a difficult and traumatic time.

Focus 3.13 Only about 10 to 20% of people at risk for HD choose to be genetically screened. Why do you think this is?

In review

- Genetic and environmental factors interact in complex ways to influence phenotypic characteristics. Genetic reaction range sets upper and lower limits for the impact of environmental factors. Where intelligence is concerned, environmental factors may create differences as large as 20 IQ points. Genotype can influence the kind of environments to which children are exposed, as when intelligent parents create an enriched environment. Genetically influenced behaviour patterns also have an evocative influence, influencing how the environment responds to the person. Finally, people often select environments that match genetically influenced personal characteristics.
- Genetic manipulation allows scientists to duplicate and alter genetic material or, potentially, to repair dysfunctional genes. These procedures promise ground-breaking advances in understanding genetic mechanisms and in treating physical and psychological disorders. Moreover, our ability to analyse people's genotypes allows for genetic screening and raises a host of practical and ethical issues.

EVOLUTION AND HUMAN NATURE

The evidence from behavioural genetics has gone a long way to convincing people that human nature is indeed influenced by evolved predispositions. However, the application of principles of natural selection to psychology has not been without controversy. Indeed a healthy scepticism is to be recommended. There is a great danger in the misapplication of

Darwin's thinking. For example, Francis Galton argued that certain traits which might have been functional and useful in the past were not so in modern Victorian England. He coined the term 'eugenics' to describe a practice of improving the human race by encouraging 'desirable' human traits through selective breeding. Those who had these 'desirable' traits should be encouraged to have children; those who did not (such as criminals) should be discouraged or prevented. Bitter experience has taught us that the principles of eugenics can be taken even further with horrifying consequences; Hitler's attempts to improve society with eugenics resulted in the death of millions in Nazi Germany.

adaptations physical or behavioural changes that allow organisms to meet recurring environmental challenges to their survival, thereby increasing their reproductive ability

Eugenics placed an unmerited moral value on evolutionary **adaptations**, which are physical or behavioural changes that allow organisms to meet recurring environmental challenges to their survival. There is no 'should' or 'ought' in evolution – life just is the way it is. People sometimes ask questions such as, 'What is the point of a mosquito?' According to the dictates of evolution, this is a nonsensical question. Natural selection is a blind, mechanical, purposeless process. It is not directed toward any particular higher goal or value. It is based upon random genetic mutations. The name of the game is long-term genetic survival and there is no particular moral merit in that. Thus, one should not consider any particular extant species evolutionarily more worthy or advanced than any another. Humans, in evolutionary terms, are not better than cockroaches because we have evolved bigger brains and are capable of more complex behaviour. If humans were to wipe themselves out in a nuclear holocaust while cockroaches survived, cockroaches would be the evolutionary success story, not us. Similarly, if an inherited tendency toward criminality were to increase the possessors' reproductive success, then in evolutionary terms, these genes would be preferable to genes that promoted more law-abiding tendencies. By placing value judgements onto natural selection, eugenicists fundamentally misunderstood the logic of the principles underlying Darwinian evolution.

FOR THE GOOD OF THE GENE

As we have seen, eugenicists proposed that we could improve the species by denying certain groups of people the right to reproduce. Yet, in *The Origin of Species*, Darwin clearly argued that natural selection does not work for 'the good of the species' or 'the good of the group'. Instead, he proposed that natural selection would always favour biological traits that promoted the reproductive success of individuals over and above what is good for the group or species. To understand why, let us consider the case of lemmings.

Lemmings are small rodents that live on the Arctic tundra. It is widely believed that when their population exceeds their food supply a large proportion of lemmings will selflessly commit mass suicide by leaping off cliffs thereby ensuring the survival of the rest of the group and in the long run the species as a whole. However, it is difficult to see how a genetic mutation that influences its carrier to commit selfless suicide could ever be selected in preference to individuals who lack these genes. Any 'selfish' individuals, who failed to sacrifice themselves by leaping off cliffs, would remain on the tundra and benefit from the reduced feeding competition. They would also continue to breed and very quickly their genes would become predominant in the population. Therefore, suicide for the good of the group or species is not an evolutionarily stable strategy: it could never establish itself as the modal trait within a population. So how do we explain the lemmings' behaviour? Actually, lemming mass suicides are a myth. There are no validated scientific observations of lemmings leaping off cliffs when their food supply runs short. Lemming populations do undergo a cyclical pattern of boom and bust (Chitty, 1996), but they do not commit suicide during the boom phases; rather some proportion of the population will serve their genetically selfish long-term individual interests by migrating.

Since natural selection does not operate for the good of the group or species, Darwinian theory seems to present a rather bleak view of existence. It seems to suggest a brutal world of ruthless competition, summed up in the infamous phrase, 'survival of the fittest' (which incidentally was first coined by Herbert Spencer not Darwin, though Darwin used and approved of it). Biological 'fitness' does not necessarily refer to the strongest or fastest or even longest-lived members of a population. If an organism lived for a thousand years, but died without doing anything to ensure that some biological part of it survived

after its death, it would be an evolutionary dead end. Darwin measured fitness in terms of the number of offspring an individual produces. However, we now know that the unit of inheritance is the gene. Thus, modern evolutionary theorists measure reproductive success in terms of the estimated number of copies of individual genes that survive into future generations (Dawkins, 2006).

Of course, as mentioned earlier, we do not just share a higher proportion of our genes with our offspring, but also our close family members. In light of this fact, William Hamilton (1963) put forward the concept of **kin selection**. He reasoned that since we share a high proportion of our genes with our close relatives, we could promote the survival of those genes by helping to ensure the survival and reproductive success of our kin. There are lots of examples in nature of animals risking or even sacrificing their lives in order to protect their kin and the genes they carry. For example, goffers or prairie dogs are more likely to risk their lives by giving predator alarm calls when close kin, rather than more distantly related individuals, are in the audience (Hoogland, 1995). Thus, the world created by natural selection is not as entirely dog-eat-dog as one might suppose.

kin selection is an evolutionary strategy in which behaviours art selected which favour the reproductive success of an organism's relatives even if that is at a cost to that organism's our survival and reproduction

reciprocal altruism is a behaviour is an organism which reduces its fitness to survive and reproduce while increasing another organism's fitness, undertaken with the expectation that the favour will be returned later

Robert Trivers (1971) has even suggested a mechanism by which self-sacrifice for non-relatives could evolve. He called the mechanism **reciprocal altruism**. The tendency to perform an immediately selfless behaviour for the benefit of non-kin could be selected as long as at a later time the recipient reciprocates the favour resulting in a net benefit to both parties. To put it in more layperson's terms, it is a case of, 'I'll scratch your back now, if you scratch my back later' (Dawkins, 1989). One of the most well studied examples in nature comes from vampire bats (Wilkinson, 1984; Carter & Wilkinson, 2013). Vampire bats make a living by biting and drinking the blood of other living animals. Seven per cent of adults and 33% of juveniles (which are bats under two years of age) fail to feed on any given night. Failure to feed is very serious, since bats die after an average of only 70 hours of fasting. They can avoid starvation by begging from other bats in their colony, some of which will regurgitate a blood meal for their starving companion. Although bats most often regurgitate for family members, Wilkinson (1984) suspected that reciprocal relationships existed between non-relatives too. To test this, he formed two captive groups from natural vampire bat clusters so that the members in the experimental groups were non-relatives. He then removed bats and deprived them of food for one or two days. Under these conditions, reciprocal partnerships of blood sharing between pairs of unrelated bats were observed.

Applying Psychological Science

Darwinian evolution would seem to suggest that we have evolved to be ruthlessly competitive and selfish (Dawkins, 2006). However, as we have seen kin selection and reciprocal altruism provide mechanisms, which can select for more positive social behaviour. Recent research has suggests that human social emotions such as guilt, shame, righteous indignation and gratitude may also be based on evolved predispositions (Shiota et al., 2004). These emotions may be ways of monitoring and maintaining mutually beneficial social relationships.

In recent years, psychologists have been studying positive social emotions in more detail. Seligman (2002) studied the emotions related to generosity and gratitude. He found that people reported higher levels of happiness by showing generosity to others than when they just pleased themselves. Similarly, Dunn et al. (2008) found people were happier when in an experiment they were instructed to spend money on others versus themselves.

Seligman et al. (2005) also investigated the effect on levels of reported happiness in terms of expressing gratitude. Participants were asked to identify and think about someone whom they were grateful to but had never explicitly thanked. They wrote and read out loud to that person a gratitude letter. The participants' levels of self-reported happiness were measured before and after the delivery of the letter. The participants reported significantly higher levels of happiness up to a month after completing the gratitude exercise. It seems we have a strong predisposition to promote our social relationships, underpinned by strong social emotions.

Try it yourself. Think long and hard about someone you are grateful to. Write an approximately 300-word letter of gratitude to that person. Be specific in the letter: say what the person had done for you, how it has affected your life and how it has made you feel. Arrange to visit the person but don't tell them why. When you see them, read the letter out loud. It may feel a bit strange, even embarrassing, but the research has shown that not only will you make the recipient of your positive social act happier, but you seem to be biologically wired with emotions that mean you will be happier too.

Culturally Universal Characteristics

Although reciprocal altruism is rare in non-human species, it is a common feature of all human groups. Culturally universal aspects of behaviour are of particular interest to evolutionary psychologists. If nearly every single human culture, even those that are relatively isolated from all other human groups, expresses a certain characteristic it suggests the expression of inborn biological tendencies that have evolved through natural selection. There exists a vast catalogue of human culturally universal characteristics and capabilities that unfold in all normally developing human beings. Consider, for example, this brief preview of commonalities in human behaviour that are discussed in greater detail in later chapters.

Chapter 9, Page 374
Chapter 5, Page 199

1. Infants are born with an ability to acquire any language spoken in the world (see **Chapter 9**). The specific languages learned depend on which ones they are exposed to. Deaf children have a similar ability to acquire any sign language, and their language acquisition pattern parallels the learning of spoken language. Language is central to human thought and communication.
2. Humans newborns are pre-wired to perceive specific stimuli (see **Chapter 5**). For example, they are more responsive to pictures of human faces than to pictures of the same facial features arranged in a random pattern (Johnson, Dziurawiec, Ellis, & Morton, 1991). They are also able to discriminate the odour of their mother's milk from that of other women (McFarlane, 1975). Facial perception and orientation may be an adaptation to promote human bonding with caregivers.

Focus 3.14 How have evolutionary principles been used to account for diverse cultures?

3. At one week of age, human neonates (i.e., babies less than one month old) show primitive mathematical skills, successfully discriminating between two and three objects. These abilities improve with age in the absence of any training. The brain seems designed to make 'greater than' and 'less than' judgements, which are clearly important in decision making (Geary, 2005).
4. According to Robert Hogan (1983), establishing cooperative relationships with other group members was critical to individual survival and reproductive success in ancestral humans. Thus humans seem to have a need to belong and strongly fear being ostracized from the group (see **Chapter 11**). Social anxiety (fear of social disapproval) may be an adaptive mechanism to protect against doing things that will prompt group rejection (Baumeister & Tice, 1990).

Chapter 11, Page 468
Chapter 11, Page 475

Focus 3.15 Do genetically based diseases provide an argument against natural selection?

5. As we will see in **Chapter 11**, there is much evidence for a set of basic emotions that are universally recognized (Ekman, 1973). Smiling, for example, is a universal expression of happiness and goodwill that typically evokes positive reactions from others (Figure 3.16). Emotions are important means of social communication that trigger mental, emotional and behavioural mechanisms in others (Ketellar, 1995).
6. In virtually all cultures, males are more violent and more likely to kill others (particularly other males) than are females. The differences are striking, with male–male killings outnumbering female–female killings, on average, by about 30 to one (Daly & Wilson, 1988). Evolutionary researchers suggest that male–male violence is rooted in hunting, establishing dominance hierarchies and competing successfully for the most fertile mates, all of which enhanced personal and reproductive survival during the course of human evolution.

FIGURE 3.16 The human smile seems to be a universal expression of positive emotion and is universally perceived in that way. Evolutionary psychologists believe that expressions of basic emotions are hard-wired biological mechanisms that have adaptive value as methods of communication.

Source: © Aldo Murillo.

Having sampled from the wide range of behavioural phenomena that have been subjected to an evolutionary analysis, let us focus in greater detail on two areas of current theorizing that relate to both commonalities and differences among people – sex and self. Before doing so, however, we should emphasize a most important principle: *behaviour does not occur in a biological vacuum; it always involves a biological organism acting within (and often, in response to) an environment.* That environment may be inside the body in the form of interactions with other genes, influencing how genes and the protein molecules through which they operate express themselves. It may be inside the mother's womb, or it may be 'out there', in the form of a physical environment or a culture. Although everyone agrees

that biological and environmental factors interact with one another, most of the debates in evolutionary psychology concern two issues: (1) How general or specific are the biological mechanisms that have evolved? (2) How much are these mechanisms influenced in their expression by the environment?

EVOLUTIONARY APPROACHES TO HUMAN MATE CHOICE

The most direct way to ensure one's long-term genetic survival is to mate and produce offspring. We should not be surprised, therefore, that evolutionary theorists and researchers have devoted great attention to sexuality, differences between men and women, and mate-seeking. This topic also has generated considerable debate about the relative contributions of evolutionary and sociocultural factors to this domain of behaviour.

One of the most important and intimate ways that humans relate to one another is by seeking a mate. Marriage seems to be universal across the globe (Buss & Schmitt, 1993). In seeking mates, however, women and men display different mating strategies and preferences. Compared with women, men typically show more interest in short-term mating, prefer a greater number of short-term sexual partners, and have more permissive sexual attitudes and more sexual partners over their lifetimes (Schmitt, Shackelford, & Buss, 2001). In one study of 266 undergraduates, two-thirds of the women said that they desired only one sexual partner over the next 30 years, but only about half of the men shared that goal (Pedersen, Miller, Putcha-Bhagavatula, & Yang, 2002). These attitudinal differences also extend to behaviour. In research conducted at three different universities, Russell Clark and Elaine Hatfield (1989; Clark, 1990) sent male and female research assistants of average physical attractiveness out across the campus. Upon seeing an attractive person of the opposite sex, the assistant approached the person, said he or she found the person attractive, and asked, 'Would you go to bed with me tonight?' Women approached in this manner almost always reacted very negatively to the overture and frequently dismissed the assistants as 'sleaze' or 'pervert'. Not a single woman agreed to have sex. In contrast, three in every four men enthusiastically agreed, some asking why it was necessary to wait until that night. Other findings show that men think about sex about three times more often than women do, desire more frequent sex and initiate more sexual encounters than do women (Baumeister, Catanese, & Vohs, 2001; Laumann, Gagnon, Michael, & Michaels, 1994). Men also are much more likely to interpret a woman's friendliness as a sexual come-on, apparently projecting their own sexual desires onto the woman (Johnson, Wadsworth, Wellings, & Bradshaw, 1992).

Despite these differences, most men and women make a commitment at some point in their lives to a long-term mate. What qualities do women and men seek in such a mate? Once again, we see sex differences. Men typically prefer women somewhat younger than themselves, whereas women prefer somewhat older men. This tendency is exaggerated in the 'trophy wives' sometimes exhibited by wealthy and famous older men. In terms of personal qualities, Table 3.4 shows the overall results of a worldwide study of mate preferences in 37 cultures (Buss et al., 1990). Men and women again show considerable overall agreement, but some differences emerge. Men place

TABLE 3.4 Characteristics of a mate

Women and men rated each characteristic on a 4-point scale. From top to bottom, the following numbers represent the order (rank) of most highly rated to least highly rated items for Buss's worldwide sample. How would you rate their importance?

Characteristic desired in a mate	Rated by	
	Women	Men
Mutual attraction/love	1	1
Dependable character	2	2
Emotional stability/maturity	3	3
Pleasing disposition	4	4
Education/intelligence	5	6
Sociability	6	7
Good health	7	5
Desire for home/children	8	8
Ambition	9	11
Refinement	10	9
Similar education	11	14
Good financial prospect	12	13
Good looks	13	10
Social status	14	15
Good cook/housekeeper	15	12
Similar religion	16	17
Similar politics	17	18
Chastity	18	16

Source: Based on Buss et al., 1990.

greater value on a potential mate's physical attractiveness, whereas women place greater value on a potential mate's earning potential, status and ambitiousness. But why might this be? Evolutionary psychologists have an answer.

sexual strategies theory (and a related model called **parental investment theory**) mating strategies and preferences reflect inherited tendencies, shaped over the ages in response to different types of adaptive problems that men and women faced

According to an evolutionary viewpoint called **sexual strategies theory** (and a related model called **parental investment theory**), mating strategies and preferences reflect inherited tendencies, shaped over the ages in response to different types of adaptive problems that men and women faced (Buss & Schmitt, 1993; Trivers, 1972). In evolutionary terms, our most successful ancestors were those who survived and passed down the greatest numbers of their genes to future generations. Men who had sex with more partners increased the likelihood of fathering more children, so they were interested in mating widely. Men also may have taken a woman's youth and attractive, healthy appearance as signs that she was fertile and had many years left to bear his children (Buss, 1989).

In contrast, ancestral women had little to gain and much to lose by mating with numerous men. They were interested in mating wisely, not widely. In humans and other mammals, females typically make a greater investment than males: they carry the foetus, incur health risks and possible birth-related death, and nourish the newborn. Engaging in short-term sexual relationships with multiple males can in the end create uncertainty about who is the father, thereby decreasing a male's willingness to commit resources to helping a mother raise the child. For these reasons, women maximized their reproductive success – and the survival chances of themselves and their offspring – by being selective and choosing mates who were willing and able to commit time, energy and other resources (e.g., food, shelter, protection) to the family. Women increased their likelihood of passing their genes into the future by mating wisely, and men by mating widely. Through natural selection, according to evolutionary psychologists, the differing qualities that maximized men's and women's reproductive success eventually became part of their biological nature (Buss, 2007).

Steven Gangestad, Martie Haselton and David Buss (2006) found that some of these mate preference patterns are more pronounced in parts of the world with historically high levels of pathogens (disease-causing germs) that endangered survival than in areas that had historically low levels of pathogens. Where diseases like malaria, plague and yellow fever are more prevalent, male factors such as physical attractiveness and robustness, intelligence and social dominance – all presumably signs of biological fitness – seem especially important to women even today. Gangestad et al. suggest that in such environments, women seem willing to sacrifice some degree of male investment in their offspring in favour of a mate who has a higher probability of giving them healthy children. To men, a woman's attractiveness and healthiness (and that of her family) also is more important in high-pathogen environments, presumably because these historically were signs of a woman who would be more likely to give birth to healthy children and live long enough to rear them.

social structure theory men and women display different mating preferences not because nature impels them to do so, but because society guides them into different social roles

Not all scientists have bought into this evolutionary explanation for human mating patterns and other social behaviours. Again, the disagreement revolves around the relative potency of interacting biological and environmental factors. In the case of mate selection, proponents of **social structure theory** maintain that men and women display different mating preferences not because nature impels them to do so, but because society guides them into different social roles (Eagly & Wood, 1999, 2006). Adaptive behaviour patterns may have been passed from parents to children not through genes but through learning. Social structure theorists point out that despite the shift over the past several decades towards greater gender equality, today's women still have generally less power, lower wages and less access to resources than do men. In a two-income marriage, the woman is more likely to be the partner who switches to part-time work or becomes a full-time homemaker after childbirth. Thus, society's division of labour still tends to socialize men into the breadwinner role and women into the homemaker role.

Given these power and resource disparities and the need to care for children, it makes sense for women to seek men who will be successful wage earners and for men to seek women who can have children and fulfil the domestic-worker role. An older male–younger female age gap is favourable because older men are likely to be further along in earning power and younger women are more economically dependent, and this state of affairs conforms to cultural expectations of marital roles. This division-of-labour hypothesis does not directly address why men emphasize a mate's physical attractiveness more than

women do, but Alice Eagly and Wendy Wood (1999) speculate that attractiveness is viewed as part of what women 'exchange' in return for a male's earning capacity.

We now have two competing explanations for sex differences in mating behaviour: the evolution-based sexual strategies approach and the social structure view. Our 'Research close-up' looks at one attempt to compare predictions derived from the two theories.

Focus 3.16 Why should the mate choice criteria of men and women overlap so much?

Research close-up

SEX DIFFERENCES IN THE IDEAL MATE: EVOLUTION OR SOCIAL ROLES?

Sources: D. M. Buss (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. *Behavioral and Brain Sciences, 12,* 1–49; A. Eagly and W. Wood (1999). The origins of sex differences in human behavior: Evolved dispositions versus social roles. *American Psychologist, 54,* 408–423.

INTRODUCTION

How can we possibly test the hypothesis that, over the ages, evolution has shaped the psyches of men and women to be inherently different? Evolutionary psychologist David Buss proposes that, as a start, we can examine whether gender differences in mating preferences are similar across cultures. If they are, this would be consistent with the view that men and women follow universal, biologically based mating strategies that transcend culture. Based on principles of evolutionary psychology, Buss hypothesized that *across cultures,* men will prefer to marry younger women because such women have greater reproductive capacity; men will value a potential mate's attractiveness more than women will because men use attractiveness as a sign of health and fertility; and women will place greater value than men on a potential mate's earning potential because this provides survival advantages for the woman and her offspring.

METHOD

Buss's team of 50 scientists administered questionnaires to women and men from 37 cultures around the globe. Although random sampling could not be used, the sample of 10,047 participants was ethnically, religiously and socio-economically diverse. Participants reported the ideal ages at which they and a spouse would marry, rank-ordered (from 'most desirable' to 'least desirable') a list of 13 qualities that a potential mate might have, and rated the importance of 18 mate qualities on a second list (see Table 3.4).

Alice Eagly and Wendy Wood wondered if men's and women's mate preferences might be influenced by a third variable, namely, cultural differences in gender roles and power differentials. To find out, they re-analysed Buss's data, using the United Nations Gender Empowerment Measure to assess the degree of gender equality in each of the cultures. This measure reflects women's earned income relative to men's, seats in parliament, and share of administrative, managerial, professional and technical jobs.

RESULTS

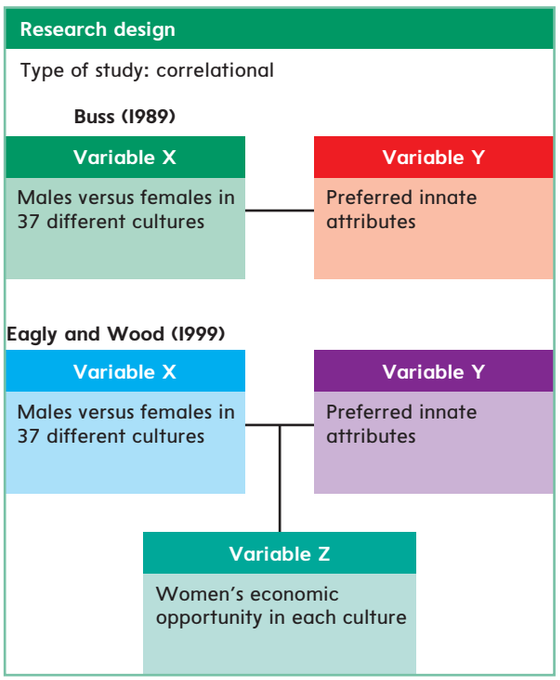
In all 37 cultures, men wanted to marry younger women. Overall, they believed that the ideal ages for men and women to marry were 27.5 and 24.8 years, respectively. Similarly, women preferred older men, reporting on average an ideal marriage age of 28.8 for husbands and 25.4 for wives. In every culture, men valued having a physically attractive mate more than women did, and in 36 of 37 cultures, women attached more importance than men did to a mate's earning potential.

EVOLUTIONARY AND SOCIAL ROLES' INTERPRETATIONS

David Buss concluded that the findings strongly supported the predictions of evolutionary (sexual strategies) theory. Subsequently, Alice Eagly and Wendy Wood analysed Buss's data further in order to test two key predictions derived from their social structure theory:

1. Men place greater value than women on a mate's having good domestic skills because this is consistent with culturally defined gender roles.
2. If economic and power inequalities cause men and women to attach different values to a mate's age, earning potential and domestic skills, then these gender differences should be smaller in cultures where there is less inequality between men and women.

As reported by Buss, the potential-mate characteristic 'good cook/housekeeper' produced large overall gender differences, with men valuing it more highly. Could



this overall trend, however, depend on differences in cultural roles or power differentials? As predicted by the social structure model, Eagly and Wood found that in cultures with greater gender equality, men showed less of a preference for younger women, women displayed less of a preference for older men, and the gender gap decreased in mate preferences for a 'good cook/housekeeper' and 'good financial prospect'. On the other hand, cultural gender equality did not influence the finding that men value physical attractiveness more than women; that gender difference was *not* smaller in cultures with greater gender equality.

DISCUSSION

Both Buss (Gangestad et al., 2006) and Eagly and Wood (2006) share an interactionist perspective on mate selection that simultaneously takes nature and nurture into account. They differ, however, on how specific and strongly programmed the biological dispositions are thought to be. When Buss found remarkably consistent sex differences in worldwide mate preferences, he interpreted this cross-cultural consistency as evidence that men and women follow universal, biologically based mating strategies. Yet Eagly and Wood (1999, 2006) insist that consistency in behaviour across cultures does not, by itself, demonstrate *why* those patterns occur. They view the mate selection preferences not as biologically pre-programmed, but rather as reflecting evolved but highly flexible dispositions that depend heavily on social input for their expression. In support of this position, they found that a commonly found social condition across cultures, gender inequality, accounts for some – but not all – of the sex differences in mating preferences.

In science, such controversy stimulates opposing camps to find more sophisticated ways to test their hypotheses. Ultimately, everyone's goal is to arrive at the most plausible explanation for behaviour. This is why scientists make their data available to one another, regardless of the possibility that their peers may use the data to bolster an opposing point of view.

Although men and women differ in some of their mating preferences and strategies, the similar overall order of mate preferences shown in Table 3.4 indicates that we are talking once again about shades of the same colour, not different colours. In fact, Buss and his co-workers (1990) found that 'there may be more similarity between men and women from the same culture than between men and men or women and women from different cultures' (p. 17).

EVOLUTIONARY APPROACHES TO PERSONALITY

evolutionary personality theory looks for the origin of presumably universal personality traits in the adaptive demands of our species' evolutionary history

Personality is an especially interesting topic to consider from an evolutionary perspective because traditionally, evolutionary approaches are geared to explaining the things we have in common. An approach called **evolutionary personality theory** looks for the origin of presumably universal personality traits in the adaptive demands of our species' evolutionary history. It asks the basic question, 'Where did the personality traits exhibited by humans come from in the first place?' The focus here is on the traits that we (and other animals) have in common. But evolutionary personality theory also tries to account for the core question in the field of personality: why do we differ from one another in these personality traits?

Previously in this chapter, we described the five factor model of personality, the leading current trait theory. Because these five trait dimensions – extraversion, agreeableness, conscientiousness, neuroticism and openness to experience – have been found in people's descriptions of themselves and others in virtually all cultures, some theorists regard them as universal among humans (Nettle, 2006). And because evolutionary theory addresses human universals, the Big Five traits have been the major focus of evolutionary personality theory.

Why should these traits be found so consistently in the languages and behaviours of cultures around the world? According to David Buss (1999), they exist in humans because they have helped us achieve two overriding goals: physical survival and reproductive success. Traits such as extraversion and emotional stability would have been helpful in attaining positions of dominance and mate selection. Conscientiousness and agreeableness are important in reproduction and the care of children. Finally, openness to experience may be the basis for problem-solving and creative activities that benefit not only the possessor but also are likely to be valued by other group members. Rewarding and encouraging these traits could be to the mutual benefit of everyone. Evolutionary theorists therefore regard the behaviours underlying the Big Five as sculpted by natural selection.

The five personality factors also may reflect the ways in which we are biologically programmed to think about and discriminate among people. Lewis Goldberg (1981) suggests that over the course of evolution, people have had to ask some very basic questions when interacting with another person, questions that have survival and reproductive implications:

1. Is person X active and dominant or passive and submissive? Can I dominate X, or will I have to submit to X?
2. Is X agreeable and friendly or hostile and uncooperative?
3. Can I count on X? Is X conscientious and dependable?
4. Is X sane (stable, rational, predictable) or crazy (unstable, unpredictable, possibly dangerous)?
5. How smart is X, and how quickly can X learn and adapt?

Not surprisingly, according to Goldberg, these questions relate directly to the Big Five factors. He believes that this is the reason analyses of trait ratings reveal Big Five consistency across very diverse cultures.

So much for commonalities in the personality traits that people exhibit; but what about the individual differences in these traits that we witness every day, and that define individual personalities? If natural selection is a winnowing process that favours certain personal characteristics over others, would we not expect people to become more alike over time and personality differences to be minimal? Here we turn to another important evolutionary concept called **strategic pluralism**, the idea that multiple – even contradictory – behavioural strategies (for example, introversion and extraversion) might be adaptive in certain environments and would therefore be maintained through natural selection. Thus, Daniel Nettle (2006) theorizes that we see variation in the Big Five traits because all of them have adaptive trade-offs (a balance of potential benefits and costs) in the outcomes they may produce.

strategic pluralism the idea that multiple – even contradictory – behavioural strategies might be adaptive in certain environments and would therefore be maintained through natural selection

Take extraversion, for example. Nettle (2006) reviewed research showing that scores on personality tests that measure extraversion are positively related to the number of sexual partners that males have and to their willingness to abandon sexual relationships with women in order to pursue a more desirable partner. These behaviours should increase the prospects for reproducing lots of offspring. Compared with introverts, extraverts also have more social relationships, more positive emotions, greater social support, and are more adventurous and risk-taking, all of which can have benefits. The trade-offs, however, are greater likelihood of risk-produced accidents or illnesses, and a higher potential for antisocial behaviour (which in the ancestral environment might have resulted in ostracism or even death and in the current environment, imprisonment). For a woman, the outgoing demeanour of the extravert may facilitate attracting a mate, but also may lead to impulsive sexual choices that are counterproductive for her and her offspring. The trait of agreeableness brings with it the benefits of harmonious social relationships and the support of others, but also the risks of being exploited or victimized by others. Another potential cost of agreeableness arises from not sufficiently pursuing one's own personal interests; a little selfishness can be adaptive. Even neuroticism, which is generally viewed as a negative trait, has both costs and benefits that could relate to survival. On the cost side, neuroticism involves anxiety, depression and stress-related illness that could shorten the lifespan and drive potential mates away. But the fitness trade-off of neuroticism is vigilance to potential dangers that could be life-saving, as well as fear of failing and a degree of competitiveness that could have adaptive achievement outcomes. Nettle believes that these trade-offs favour evolutionary variation in the Big Five traits and that the specific environment in which our ancestors evolved made it more or less adaptive to be an extravert or an introvert, agreeable or selfish, fearful or fearless, conscientious or immoral, and so on. This would help account for genes favouring individual differences on personality dimensions and for the great diversity we see in personality trait patterns.

Focus 3.17 If high levels of extraversion are associated with a greater number of sexual encounters, why hasn't natural selection ensured that all humans are extrovert?

Evolutionary theorists also account for individual differences in personality traits by focusing on gene–environment interactions. Evolution may provide humans with species-typical behaviour patterns, but environmental inputs influence how they are manifested. For example, dominance may be the behaviour pattern encouraged by innate mechanisms in males, but an individual male who has many early experiences of being subdued or dominated may develop a submissive personality.

As we have seen throughout this chapter, genetic factors underlie evolutionary changes, and they strongly influence many aspects of our human behaviour. Genes do not act in

isolation, however, but in concert with environmental factors, some of which are created by nature and some of which are of human origin. Together, these forces have forged the human psychological capabilities and processes that are the focus of psychological science. Levels of analysis show how the causes of behaviour can be studied.

Levels of analysis

factors influencing human behaviour

PSYCHOLOGICAL

- *Distal*: evolutionary-based psychological mechanisms (e.g., learning capabilities, emotions, thinking abilities)
- *Proximal*: mental, emotional, motivational and behavioural mechanisms and processes; individual differences in capabilities, personality and other characteristics; gender-based characteristics

BIOLOGICAL

- *Distal*: evolved human genome produced in part by natural selection
- *Proximal*: individuals' genotypes, biological structures and processes produced by gene–environment interactions

ENVIRONMENTAL

- *Distal*: environments that required adaptations and fostered natural selection
- *Proximal*: individuals' shared and unshared environments, past and present cultural factors

Human behaviour

In review

- Evolutionary psychology focuses on biologically based mechanisms sculpted by evolutionary forces as solutions to the problems of adaptation faced by species. Some of these genetically based mechanisms are general (e.g., the ability to learn from the consequences of our behaviour), whereas others are thought to be domain-specific, devoted to solving specific problems, such as mate selection.
- Evolution is a change over time in the frequency with which particular genes, and the characteristics they produce, occur within an interbreeding population. Evolution represents an interaction between biological and environmental factors.
- The cornerstone of Darwin's theory of evolution is the principle of natural selection. According to this principle, biologically based characteristics that contribute to survival and reproductive success increase in the population over time because those who lack the characteristics are less likely to pass on their genes.
- Among the aspects of human behaviour that have received evolutionary explanations are human mate selection and personality traits. In research on mate selection, evolutionary explanations have been tested against hypotheses derived from social structure theory, which emphasizes the role of cultural factors.

Recommended Reading

CONTEMPORARY

Plomin, R. Dearies, J.C., Knopik, V.S. & Neiderhiser,J.M. (2013). *Behavioural Genetics* (6th edn). New York: Worth.

Rutter, M. (2006). *Genes and behavior: Nature-nuture interplay explained.* Oxford: Blackwell.

CLASSIC

Dawkins, R. (1976). *The Selfish Gene.* New York: Oxford University Press.

Lorenz, K. (1961). *King Solomon's Ring* (Trans. M. Kerr Wilson). London: Methuen.