Sample Translation

Evolutionary Thinking: How Darwin shaped our world view

(Evolutionair denken. De invloed van Darwin op ons wereldbeeld)

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(Amsterdam: Nieuwezijds, 2006)

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Sexual Selection

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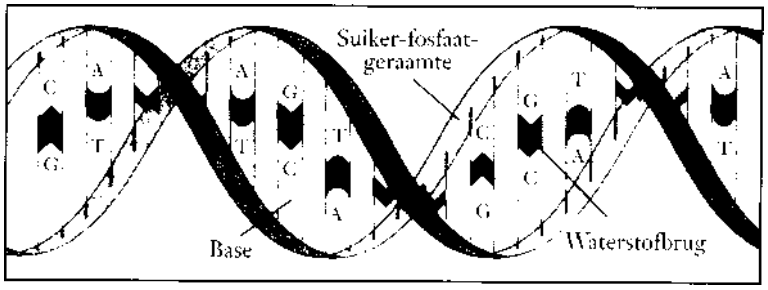
THE DOUBLE HELIX

When modern evolutionary synthesis was completed at the end of the 1930s, it did not mean there would be no new developments. Just the opposite in fact; in the second half of the twentieth century, evolutionary biology would develop into one of the central pillars of modern-day natural science. Darwin was shown to be more relevant than ever. The most important development was that of molecular biology, the study of the physical foundations of life. Once again, this development marked an important break with the preceding period. In the first half of the twentieth century, many scientists and philosophers still adhered to the doctrine known as vitalism, the idea that living creatures are essentially different from non-living matter. According to vitalists, living creatures, in contrast to lifeless entities, possess an intangible spark of life, one that fills everything that lives with a spiritual life force. Molecular biology would show this premise to be irrelevant. Life has a physical basis, and no mysterious, intangible substances or processes are needed to explain its uniqueness.

In 1953, the Englishman Francis Crick and the American James Watson discovered the molecular structure of DNA: the double helix (illustration 2.1). In 1962 they received the Nobel Prize for their discovery. All life on earth was shown to be made up of sugar-phosphate strands, which form a double spiral when wound around their common axis. This spiral “backbone” is made up of four bases, namely adenine (A), cytosine (C), guanine (G) and thymine (T). The bases are complementary: adenine and thymine form a pair, as do guanine and cytosine. The strands are held together by hydrogen bonds between the pairs of

bases. The order of the bases in the spiral forms the genetic code, the blueprint of all organisms.



Schematic diagram of the structure of DNA. A = adenine, T = thymine, C = cytosine, G = guanine
Illustration 2.1: The double helix.

The discovery of the double helix was yet another indication of the common origin of life on our planet. All organisms turned out to be made up of the same basic building blocks. Molecular biology also makes it possible to test suppositions about the course of evolution. We can reconstruct evolutionary history using what is known as the "molecular clock." Research has shown that random mutations often occur at a consistent rate. Mutations in mitochondrial DNA in particular have been shown to occur so frequently that they can be compared to the ticking of a clock. (Mitochondria provide cells with the energy they need; these organelles occur in all plant and animal cells. Mitochondrial DNA is passed down only through the mother, in contrast to the DNA in the cell nucleus, which comes from both parents.) The regularity with which mutations occur in cell organelles allows biologists to "count backwards" and determine the point at which species began to grow away from each other. If two species have many differences in their organelle DNA, this means they evolved in different directions long ago. If there are only small differences, this took place relatively recently. For example, the genetic differences between humans and chimpanzees amount to only a few percent, whereas there are far more such differences between humans and fruit flies. If the molecular clock also ticked regularly in the past – and we have reason to believe this is probable – we can calculate that the common ancestor of humans and chimpanzees must have lived around six million years ago. Conversely, those lines of descent that would result in humans and in fruit flies went in different directions some hundreds of millions of years ago.

Before the advent of molecular biology and modern genetics, evolutionary biologists had to rely on morphology (the study of the outward appearance and features of organisms) when studying relatedness. However, outward features do not tell the whole story. For example, there are considerable morphological differences between a Great Dane and a dachshund. But there is only a tiny difference in their genetic makeup when you look at their DNA, and this occurred only recently as a result of artificial selection. In spite of the obvious differences, the Great Dane and the dachshund belong to the same species: *Canis familiaris.* In this way, molecular biology offers a relatively reliable instrument for testing suppositions about relatedness and the evolutionary history of species.

Molecular biology also showed that genetics is much more complicated than the first generation of neo-Darwinists presumed. For example, an organism's phenotypical characteristics are not coded separately in individual genes, nor does natural selection reward or penalise having such genes. Things are much more complex. There is rarely a direct correlation between an individual gene and a certain physical characteristic. It is more a matter of a hierarchy of genes and gene complexes that may or may not interact to regulate one another. A single gene can also be involved in the formation of a number of different traits, which is called pleiotropy. Because of this, the underlying genetic building plan does not have the final say on what an organism will look like. Environmental factors play at least as great a role, and can cause two genetically identical organisms to develop very differently. This means there is some degree of latitude in how an organism develops, a fact biologists refer to as "phenotypic plasticity."

THE EVOLUTIONARY ALGORITHM

All in all, evolutionary biology has now been well substantiated in a number of ways. In the last chapter we saw that biological evolution is a process that involves three elements, namely, variation, selection, and reproduction. Random variation is the source and fuel of evolution. As a rule, organisms within a population differ from each other in many respects. Some traits offer advantages

with regard to survival and reproduction, giving the possessors of these traits greater *fitness*: the ability to produce offspring. Other traits have an adverse effect in the sense that they lower the chances of survival and reproduction. Variation in a population is the result of mutations and genetic recombination, the rearranging of genes through sexual reproduction. When a specific variation is hereditary, this can change the makeup of a population. The variation that occurs in a population is always "random" – in other words, variation does not anticipate selective pressure. A population that for one reason or another is no longer adapted to its environment can only wait for an accidental and more advantageous variation to come along. So, variation is not "directed," as Lamarck believed. The efforts made by individual organisms have no affect whatsoever on the variation that arises.

Natural selection is the second element in the evolutionary mechanism. We can rightfully refer to this component as the "engine" of evolution. Selection means there is an identifiable reason why some individuals produce more offspring than others. Natural selection discriminates based on differences in the fitness of organisms. Because of this, selection is by definition *non-random.* After all, differences in reproductive success do not happen at random. In general, individuals who are best adapted to their environment will produce the most offspring. Natural selection is a filter that retains favourable variations and does away with undesirable ones.

Reproduction is the third and final element of the evolutionary mechanism. Reproduction can be considered to be the key to evolution because in a certain sense it opens the door to immortality. By reproducing, organisms are able to pass on their genetic information to the next generation, which means genes are potentially immortal. The fact that organisms are able to reproduce also means there is a cumulative aspect to the evolutionary filtering process in that it allows positive characteristics to accumulate. Generally, genes that produce favourable effects are copied more often than those that produce undesirable ones. Traits that increase fitness spread throughout the population and are further reinforced, and

traits that reduce fitness are diminished or eliminated. In this way, the population as a whole becomes a flexible entity that can gradually change its makeup and adapt to changing circumstances.

Taken as a whole, these three elements form the evolutionary algorithm of variation, selection, and reproduction, otherwise known as a VSR algorithm. An algorithm is a simple formula or procedure that, when followed, generates a specific outcome. The evolutionary VSR algorithm generates biological adaptations and leads to populations that are able to adapt to changing environments. Evolution is a cumulative filtering mechanism whereby the outcome of each round of selection is in turn used as input for the next round. If this kind of cumulative filtering process goes on long enough, it can produce the most amazing adaptations. Take the eye, for example. The eye is a favourite among creationists and other opponents to the theory of evolution, who claim that a sense organ as complex as the eye could never have developed by chance. What opponents to the theory of evolution overlook is that random variation is only one of the ingredients in the recipe for evolution. Evolution also has a non-random element, namely selection. And if you then add in the third element, reproduction, you have the entire VSR algorithm. Only the combination of variation, selection, and reproduction results in the mechanism that can simulate intelligent design. Eyes have evolved independently of each other many times, in organisms such as vertebrates, insects, and mollusks. All these different kinds of eyes very likely started out as a simple light-sensitive cell or photoreceptor. Over the course of tens of millions of years, each improvement in the design – no matter how small – was retained and passed on, because in a dangerous world, each slight improvement in sight is a bonus. This ultimately led to the complex compound eyes of insects, and the camera eyes of vertebrates. In short, the evolution of complex senses and organs can only be understood when you consider all three of the algorithm’s components. Chapter 1 mentioned the example of the monkey sitting in front of a word processor. The chance that the animal will produce one of Shakespeare’s plays by hitting random keys is indeed incredibly unlikely. But

if you were to add a cumulative filtering mechanism to the word processor, one that with infinite patience would arrange the letters, spaces, and punctuation in the correct order of, say, *Macbeth*, then the monkey's random keystrokes could take him quite a way in the right direction.

Almost every modern handbook on evolutionary biology uses the example of the peppered moth (*Biston betularia*) to illustrate how evolution works and how creative it is. The peppered moth is a small, inconspicuous moth found all over Europe. In England, the trials and tribulations of this species have been well documented. In the first half of the nineteenth century, all these moths were light coloured. Their colour meant they would not be noticed against a background of lichens, which were then very common. This camouflage was the result of natural selection. Light-coloured moths had a considerable advantage because they were not noticed by insect-eating birds and other predators. But then something changed dramatically. The industrial revolution and the air pollution it brought with it caused the lichens – which are extremely sensitive to pollution – to disappear, and everything was covered with a thin layer of soot instead. This meant that the light-coloured butterflies were no longer camouflaged, and insect-eating birds had a heyday. But to everyone's amazement, a few years later dark-coloured variants of the peppered moth suddenly began to appear. Evolution had stumbled across the solution by trying out random variations. Natural selection rewarded the dark variants. After all, a dark individual was better camouflaged and so was harder for insect-eating creatures to see. At first, the dark variants were rare, but a few decades later this trait had spread throughout the entire population, and there were almost exclusively black variants of the peppered moth – a phenomenon known in biology as "industrial melanism." These days much of the heavy industry is gone and air pollution is not as serious as it was during the nineteenth century. Lichens have once again returned to England, and the soot has by and large vanished. Today you can find both light and dark variants of the peppered moth. Eventually the population might again be made up of only light-coloured individuals.

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Evolution and Religion

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THE DEVIL'S CHAPLAIN

In September 1842, Darwin, his wife Emma, and their two small children moved from London to Down, a small village in Kent approximately twenty-five kilometres south of the capital. Just outside the village, Darwin had bought a pretty country house with a large garden for £ 2,200. In Down House, the family steadily grew and Darwin continued to work on his secret project: providing further substantiation for his theory of evolution. He was not yet ready to publish his ideas. Darwin believed he first had to come up with enough convincing evidence for his theory, and he also feared the commotion that would undoubtedly ensue as soon as he made his ideas public. He believed that for the time being it would be better for him to do further research in private. Down House and the rolling green hills of Kent offered the peace and quiet he needed.

In October 1846, Darwin began his comparative study on barnacles, which belong to the order Cirripedia. Such an in-depth study might be able to shed more light on how these organisms evolved. This meticulous study took all of eight years to complete. The barnacles were rewarding as an object of study: not much was known about them at that time, except for the fact that they were not molluscs (Mollusca) like mussels and snails, but crustaceans (Crustacea), related to lobsters and crabs. However, in contrast to lobsters and crabs, barnacles cannot move about under their own power, although they are able to attach themselves to ships and large, moving marine animals like whales. Darwin himself collected a vast number of Cirripedia, and he was also sent specimens from all over the world, and was even able to get his hands on the collection in the British

Museum. There were cirripedes everywhere in Down House. (Under the impression that all adults collected and studied these animals, one of Darwin's children asked when playing at a friend's house, "Where does your father do his barnacles?")

His study of cirripedes reinforced Darwin's conviction that evolution was propelled by natural selection, in that the Cirripedia are very diverse, and have adapted to a wide range of environments. There is a large degree of variation even within a species. It would seem that during evolution, the basic plan for these animals was constantly being updated, whereby the organisms could adapt to new conditions. The study also showed the importance of embryological evidence, because although substantial differences often exist between adult cirripedes specimens, the larval stages are so similar it would seem inevitable to conclude that they descended from a common ancestor. In the end, Darwin's research into barnacles resulted in two large volumes, published in 1851 and 1854, that described all known cirripedes. However, these works did not refer directly to evolution – and so the secret project continued unabated.

This relatively idyllic existence in Down was disrupted by an event from which Darwin would never completely recover. In 1850, Darwin's nine-year-old daughter Annie (Anne Elizabeth) became seriously ill. Although the girl's health had been problematic for some time, the situation had not been life threatening till then. In March 1851, though, Annie's condition became so much worse that Darwin took her to the spa town of Malvern in Worcestershire. Darwin had himself undergone a "water cure" in Dr. James Gully's clinic, and he believed that this doctor (a charlatan, according to some) might also be able to help Annie. Fate, though, decided otherwise.

On Wednesday April 23, 1851, Annie – who had just turned ten – died in Malvern from what Gully called a "typhoid fever." Darwin did not leave her bedside during her final days, while Emma (who was heavily pregnant) waited anxiously back in Down. Annie was Darwin's favourite daughter. A week after her death, he wrote a heartrending In memoriam in which he mourned the "cruel

and bitter loss" of the girl. Annie's death robbed Darwin of the last remnants of his religious beliefs. Although in the decades preceding his daughter's death he had increasingly begun to question the doctrine of his Anglican upbringing, Annie's death brought an end to any remaining religious sentiment he may have still had. He had lost his belief in a benevolent and loving God, and would never again seek comfort in religion. Annie's death was senseless, a brutal fact of a purposeless natural world.

However, Darwin did not flaunt his lack of faith. He avoided the subject whenever possible, mainly out of respect for his wife Emma, who was deeply religious. He did not want to hurt her. For her part, Emma did not balk at editing Darwin's writing on this subject. For example, in the original version of his autobiography Darwin writes: "We must not overlook the probability of the constant inculcation in a belief in God on the minds of children producing so strong [...] an effect on their brain not yet fully developed, that it would be as difficult for them to throw off their belief in God, as for a monkey to throw off its instinctive fear and hatred of a snake." Emma was horrified by this passage, and had it removed from editions published after Darwin's death. She was comforted by the thought that Annie was in heaven, and that the family would be reunited in the hereafter. Darwin was no longer able to believe in this. There was no revelation, no hereafter or salvation. Religion was completely meaningless.

Darwin, who had received a degree in theology in Cambridge with the intention of becoming a clergyman, became the "devil's chaplain" after his daughter's death. In a letter from 1856 to his friend, the botanist Joseph Hooker, he half-jokingly referred to his own situation: "What a book a devil's chaplain might write on the clumsy, wasteful, blundering, low, and horribly cruel works of nature." In a letter written four years later to the botanist Asa Gray, his tone was unchanged: "I cannot persuade myself that a beneficent and omnipotent God would have created the Ichneumonidae [a kind of wasp, CB] with the express intention of their feeding within the living bodies of caterpillars or that a cat should play with mice." Annie's death opened Darwin's eyes to harsh reality:

nature is neither good nor bad, but even worse, it is terribly indifferent. In such a world, there is a devastating absence of God.

AN AMERICAN STATE OF AFFAIRS

The philosopher Friedrich Nietzsche believed God was dead (and that we killed him). Darwin, though, proved that God never existed. At least, this might seem to be a fitting way to summarise the intellectual legacy of both thinkers, were it not that such a statement would be rather premature. While it is true that Darwin made short shrift of one of the most significant proofs of the existence of God – the *argument from design* – this does not mean that evolution and religion have become completely incompatible. Even Pope John Paul II said in 1996 that the theory of evolution is not in conflict with official Catholic doctrine. However, biologists like Richard Dawkins and Ronald Plasterk think you have to be crazy to believe in God after Darwin. Others, like biologist Stephen J. Gould and philosopher Michael Ruse, take a stand somewhere in between. They suggest there cannot possibly be a conflict between religion and evolution because they have to do with entirely different things. How should we interpret these considerable differences of opinion?

The debate on the supposed incompatibility of evolution and religion has been mainly an American affair, but recently the discussion was sparked off in the Netherlands as well. In 2005, uproar ensued when Dutch education minister Maria van der Hoeven (from the CDA party, or Christian Democratic Appeal) called for a dialogue between evolutionary biologists and religious believers. According to her, the theory of evolution was “incomplete,” and she considered the idea of a creator behind life to be a valid alternative. Van der Hoeven pointed to the ideas of *intelligent design* (ID), an American movement dating from the 1990s that consider there to be an intelligent designer behind life on earth. All hell broke loose for a time: questions were asked in parliament, the opinion pages of the newspapers were filled with mainly sarcastic commentaries (“Stick to your Bible meetings, Maria!”), and academics were up in arms because politicians

were meddling with scientific content. No one had expected to see such an American state of affairs in the Netherlands.

Emotions ran high because at issue was the separation of Church and State. According to critics, it was very dangerous to present ID as a *scientific* alternative to the theory of evolution. The next step might be to include ID teachings in the school curriculum. Van der Hoeven was guiding us towards the rocks; she seemed to want to go back to the dark ages. Even among some of the professors at Amsterdam's Vrije Universiteit (Free University), which has long been known as a Protestant-Christian stronghold, the appeal by the minister did not go down well. In the science supplement of the newspaper *de Volkskrant*, they distanced themselves publicly from ID ideology. A biology instructor from the very same university failed a number of Muslim students after they turned in papers in which they dismissed the theory of evolution as a Western fallacy. The students had taken their texts from a fundamentalist website. A striking detail in this whole controversy was that in calling for a debate, the education minister had this specific group of non-native Dutch people in mind: the "intercultural" debate on evolution could help Muslims in the Netherlands bridge the gap between religion and science. With the help of ID, they would find it easier to enter the Valhalla of modernity.

Religion is making a comeback, if it was ever actually missing. In the "heathen" country of the Netherlands, as well, secularism has had its day, if for no other reason than because of a steady influx of immigrants who do believe in God. As a result, the debate on evolution versus creation – which had been virtually non-existent in this country – has also flared up here in the lowlands. Increasingly, the theory of evolution is seen as a threat because it might attack religious doctrine. Ethnic Dutch people have also put in their two cents' worth. For example, Cees Dekker, professor of molecular biophysics in Delft, recently took a stand in favor of ID. Along with some of his fellow believers, he published a book criticising neo-Darwinism. According to Dekker, evolution is driven by an intelligent force, because biological complexity cannot arise by chance.

Because the ID ideology came from the United States, it might help to examine the background and history of the controversy more closely. In the US, this apparent clash between evolution and creation has led to heated arguments and legal mudslinging that have been taken all the way to the Supreme Court. The theory of evolution has always been a thorn in the side of Christian fundamentalists, in particular, in what is known as the Bible Belt – the American South and Midwest. Darwin has been considered to undermine Christian values and to incite young people to commit immoral acts. After all, if children learn they are no more than animals, they will also start to act like animals. They would be godless, and a law unto themselves.

But it is not only the fundamentalists who struggle with the theory of evolution. The image of American public opinion revealed in a recent Gallup poll was disconcerting. Those surveyed were asked the following questions: “Can you indicate which of the following statements comes closest to expressing your own ideas about the origin and development of humans?”

A. God created humans more or less in his own image sometime during the past ten thousand years.
B. Humans developed from more primitive life forms over the course of millions of years.
C. Humans developed from more primitive life forms over the course of millions of years, but God guided this process.

The outcome of the opinion poll speaks for itself. Forty-six and forty percent of those questioned agreed with statements A and C respectively, while only nine percent agreed with statement B. Five percent had no opinion. However, the outcome came as no surprise to insiders – in the US, the acceptance of Darwinism has always been problematical. For nearly a century, there has been an ongoing struggle as to whether the theory of evolution should be taught in public schools. For example, in 1925 a teacher in the state of Tennessee had to appear in court

because he had talked about evolution in a public school. The teacher, John Scopes, was found guilty and ordered to pay a fine of one hundred dollars. The court case became known as the "Monkey Trial," referring to the idea that humans descended from monkeys (an idea that is inaccurate, though, because humans evolved from hominids).This trial would develop into one of the most controversial trials in American history, and was immortalised in the 1960 Hollywood film *Inherit the Wind* with the actors Spencer Tracy and Frederic March. Even though an appeals court later acquitted John Scopes on a technicality, the Monkey Trial created an important precedent. Most Americans considered the theory of evolution to be a treacherous idea that had to be fought tooth and nail. Following Tennessee's example, anti-evolution laws were passed in the states of Mississippi, Arkansas, Oklahoma, and Florida. The theory of evolution was removed from the public school curriculum. In its place came the familiar story of creation as recorded in the Bible, in the book of *Genesis*: the earth is no more than six thousand years old, all creatures were created by God over the course of six days, and humans have a special position because they were created in God's likeness and were put in charge of the earth.

The tide only began to turn in the 1960s. In 1968, the Supreme Court ruled that the theory of evolution should no longer be suppressed and that young people should be allowed to learn this. The decision was prompted in part by the fear that, compared to the Soviet Union, science in the United States was lagging behind. The heathen Soviets had achieved resounding victories in space, and there was the fear that the communists would soon surpass the Americans in the areas of science and technology. However, the Christian lobby did not take this lying down, and started a counteroffensive: they introduced *creation science*, a "scientific" theory that had just as much right to be taught as the theory of evolution. As one might imagine, c*reation science* follows the literal interpretation of the creation story. What is important to realise is that it was not the curriculum of social studies or world-studies classes that was at issue, but that of *science classes*: physics, chemistry, and biology. The creationists wanted both

the theory of evolution and the story of creation to be included in the curriculum. Students should be allowed to make up their own minds as to which was the most plausible theory.

However, the creationists had to back down: in 1982, a judge in the state of Arkansas ruled that *creation science* was not a true science, but a way of promoting Christianity. Creationists do not conduct research, but instead put forward an ideology that cannot be tested. Because of this, *creation science* should not be part of biology lessons. In addition, there was growing insight among some of the ideology's supporters that the Bible should not always be taken literally. This divided the movement into two camps, one moderate and the other orthodox. Some inveterate creationists continued to maintain that God placed fossils in the ground to test our faith, while others acknowledged that the earth was more than six thousand years old, and that Noah's ark would simply have been too small to accommodate all the different kinds of creatures in existence. So did evolution take place after all?

Since the 1990s, the powerful Christian lobby in the US has put on new clothes in the form of the previously mentioned *intelligent design*. In contrast to creationists, the proponents of ID no longer take the Bible literally, and they acknowledge the scientific facts. But in their view, the theory of evolution does not tell the whole story. Although ID agrees that present-day life forms came from earlier forms of these creatures, it argues that the Darwinian explanation for this is incorrect. It is not a blind process of selection that underlies evolution, but rather an intelligent reason: evolution is guided by a divine hand. So, ID can be considered to be a pared-down version of *creation science*: creationism *lite*.

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Evolution and Morality

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THE FOUNDATIONS OF MORALITY

From time immemorial, people have considered morality to be of a higher order, something that, to borrow a term from Dennett, came out of the clouds on a "skyhook." According to orthodox Christians, our awareness of good and evil stems from the fall of Adam as recorded in the book of *Genesis*: in the Garden of Eden, humans fell from a state of innocence into one of guilt. When tempted by the snake, Eve tasted the forbidden fruit of the Tree of Knowledge of Good and Evil, and since then human beings have been saddled with a conscience. For a long time, ethics – the study of good and evil – was also a theological and philosophical matter. This was based on the idea that in the end morality has a divine foundation, because our awareness of good and evil comes from God. According to this view, morality is reserved only for humans, creation's crowning glory. Animals have no awareness of either God or his commandments.

However, the accepted view of morality has come increasingly under pressure. Ethics has no absolute foundation, nor does it have a divine origin. According to a growing group of thinkers and scientists, our ability to act morally is not something determined on high, but is rather an intrinsic part of our nature. Morality comes not from "above" but from "below": it is rooted in inherited dispositions that have been shaped by evolution. In the same way that we possess inherent linguistic ability, we also possess natural "moral ability." Because of this, evolutionary psychologists and sociobiologists believe that the natural sciences can be used to study the rise and development of morality. According to Edward O. Wilson, the father of sociobiology, research into the biological roots

of morality will in the end enable us to achieve a wiser and more sustainable social order. Ethics will move forward when we place it within the framework of the natural sciences. Insights from evolutionary biology, primatology, and game theory will provide us with more in-depth knowledge, and this in turn will enhance our moral principles. According to Wilson, ethics that ignore the natural foundations of morality are structurally incomplete.

Sociobiologists and evolutionary psychologists argue that one of the reasons moral systems emerge is the necessity for conflict management and cooperation. Morality arose to steer the social order in the right direction. The fact that people from entirely different systems of belief often have the same basic moral codes indicates that morality is firmly embedded in our nature. Nowhere is theft, rape, and murder perceived to be desirable, while virtually all cultures consider generosity, unselfishness, and willingness to cooperate to be virtues. For this reason, morality is perhaps not the *product* of our culture and civilisation, but the opposite: civilisation is the result of our morality, which has its roots in biology.

The fact that morality has a natural origin suggests that in this regard there is not a gap but a continuum between humans and animals. According to primatologist Frans de Waal, we share our moral sentiments with other mammals. “Hominids like chimpanzees and bonobos express anger, indignation, shame, and sympathy that are remarkably similar to human emotions. Some animals also seem to have a conscience: they realise there are rules, and that these rules can be broken. As mentioned earlier, according to De Waal and other researchers, our morality arose from the need to cooperate, an instinct we share with many other social animals. As we have already seen in Chapter 5, cooperation is based on two simple evolutionary mechanisms, namely, kin selection and reciprocal altruism. We will see how the principle of reciprocity in particular was crucial to the development of morality in humans and animals.

THE SOCIAL CONTRACT

In centuries past, philosophers have been tormented by the question of how cooperation can exist in a world made up of egoists with no central authority?

One famous answer to this question came from the seventeenth-century English philosopher Thomas Hobbes. According to Hobbes, before there were governments there was a state of nature made up entirely of egoists. Because of the merciless competition between these individuals, life was “solitary, poor, nasty, brutish, and short.” Hobbes likened the state of nature to a state of war, where individuals compete with each other to survive. The only remedy for this kind of war was to appoint a sovereign. A sovereign is a monarch or ruler who keeps an eye on things and if necessary, deals with those individuals who break the rules. By appointing such a ruler, people surrendered a degree of their personal freedom, because they then had to follow certain rules. But they also received something in return, namely, personal safety. By concluding a social contract with the sovereign, the state of nature became a civil society in which the rights of individuals were protected by the government. Hobbes' social contract is an example of what is known as a subjection contract: individuals become subjects of a sovereign, who makes sure things run smoothly.

However, other thinkers – such as the eighteenth-century French philosopher Jean-Jacques Rousseau – responded very differently to the question as to how social order emerges. In contrast to Hobbes, Rousseau argued that in the state of nature people were actually good. Rousseau painted a picture of the noble savage who lives in harmony with others of his kind in a natural setting. Before the invention of property and governments, people lived together in freedom and equality. It was only with the rise of the social and political state that they became corrupted and harmony was destroyed. In other words, civilisation actually makes people unfree, unequal, and decadent. One of Rousseau’s most well-known pronouncements reflects this: Go back to nature! Rousseau did not agree with Hobbes that we conclude a social contract with a ruler or a government. Rather than a subjection contract, Rousseau argued in favour of an association contract. People do not make themselves subject to a sovereign, but to a community in which everyone is associated. By doing so, people do not submit themselves to something or someone but to an abstraction, namely the general will (la volonté

générale). According to Rousseau, the goodness and harmony of the state of nature will then be redeemed.

The eighteenth-century Scottish philosopher Adam Smith took a stand somewhere in the middle. Smith acknowledged that society can be organized in a variety of ways. However, the most “natural” system is the liberal, free-market economy in which individuals try to maximise their own prosperity, while complying with certain government rules. Smith argued that such a system actually comes into being “spontaneously” through the countless transactions that take place between individuals. The free-market economy emerges from and is guided by an “invisible hand.” A division of labour soon emerges and this leads to interdependence. After all, we cannot be baker, butcher, brewer, and chimney sweep all at the same time. So, the social order does not emerge by design, but rather as a matter of course. Smith and other classical liberal thinkers assumed that people are rational and in pursuit of their own self-interest, and that this benefits society as a whole.

Although in daily life, the fact that people help each other is never seen as a problem, it is a problem in terms of biology. The question is in fact how exactly cooperation arises and persists in a Darwinian world characterised by selfishness. This is because such self-interest would seem to offer little room for empathy, self-sacrifice, and compassion, let alone high moral principles. Smith suggested that cooperation and order can come into being without being imposed from above. But how can society as a whole possibly benefit from selfish individuals? Why is there no systematic exploitation of well-meaning individuals? Why is it that society is not disrupted by free riders, spongers who take advantage of the cooperative system without doing anything in return? And which principle underlies our willingness to cooperate with each other? Could cooperation be a strategy that, in the end, is also based on self-interest? To be able to answer these questions, we have to formalise the problem, which happens in game theory.

Epilogue

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According to Richard Dawkins at the beginning of his book *The Selfish Gene*, "If superior beings from space ever visit earth, the first question they will ask, in order to assess the level of our civilisation, is: 'Have they discovered evolution yet?'" Dawkins says, "Intelligent life on a planet comes of age when it first works out the reason for its own existence." On our planet we have Darwin to thank for this insight, and for our maturity. Darwin's theory of evolution is an intellectual and scientific milestone that is difficult to match, let alone surpass. Until now, in the history of science and philosophy no single idea has ever had such an impact, and never before were so many facts explained with so few suppositions. Also, the way in which Darwin's theory accounts for these facts is of such elegance and beauty that even the most persistent myths about how the world was created fairly pale in comparison. Darwin has forever changed the way we see the world and ourselves: he has ushered us into a new era. We understand the process that has given us our existence and as a result, the process of evolution has become conscious of itself, perhaps for the first time in the universe.

In this book I have made a bold attempt to describe the impact and scope of Darwin's legacy, even though such an attempt is doomed to failure from the start. This is because the Darwinian revolution has not yet played itself out, and one hundred and fifty years since the publication of *The Origin of Species*, the implications of Darwin's discovery are still being felt in a great many areas of science. The theory of evolution has proved to be relevant not only to biology, but also to theology, philosophy, psychology, sociology, anthropology, linguistics, medicine, game theory, and the list goes on. Today there is virtually no area of science that has *not* been influenced by Darwin's "dangerous idea." To

once again use the imagery of Daniel Dennett: Darwin's discovery is like a universal acid with a pervasive, corrosive effect, eating away at everything, unstoppable, leaving everything altered in its wake.

Darwin's universal acid has eaten away at a number of deep-seated, age-old beliefs. The Creator has not assigned humans a special status, nor have we been created in the likeness of a supreme being. The immortal soul we are said to have received from on high can be relegated to the realm of myths, as can the idea that our existence has a deeper, transcendent significance. Evolution creates the illusion of a purpose and a plan that do not actually exist. Humans are not fallen angels, but primates who have climbed up the evolutionary ladder. It is not strange, then, that many people are still hostile to the theory of evolution. The shock is simply too great.

In the conceptual revolution Darwin set in motion, he turned the usual way of explaining things on its head, replacing the ancient idea of a creative intelligence underlying our existence with the insight that life has developed through a natural process involving prebiotic, self-replicating macromolecules. Rather than a *top-down* explanation whereby a higher, divine authority created all of life in a single stroke, Darwin gave a *bottom-up* explanation: starting from a primitive beginning, a natural and gradual process led to the present forms of life. Life did not come down from heaven, but worked its way up through the mud. Since Darwin, we know that a complex design does not necessarily imply an intelligent designer. The blind and purposeless process of cumulative natural selection can also produce stunningly beautiful creations.

But aside from shocking implications, the theory of evolution also brings with it many extraordinary new perspectives. For example, in its deepest essence, all life on our planet – all the way down to minute filaments and cells – is one. In every one of us, an uninterrupted chain of replication leads back to the very earliest beginnings. This genealogy is not some thousands of years old, as told in some of the myths that have been handed down, but four billion years old. When we follow our own lineage back in time, back to the arrival of the first hominids,

the dawn of the primates, the appearance of mammals and the first vertebrates, which explored the land and the seas, we arrive in the end at the Cambrian explosion and the era of the microbes and single-celled organisms that preceded this. As we go back in time, more and more lines of descent come together, first the most recent twigs and offshoots of the evolutionary tree, and finally, the main branches that emerge from the trunk one by one. Such a unique and ancient oneness commands respect, and creates a bond no myth can match. So Darwin did not demystify our existence, as some people believe, but actually made it more profound in a breathtaking way. At the same time, this insight brings with it obligations, for if all life on earth is one, and the evolutionary process has become conscious of itself and what it can do, then we are responsible for making sure this life continues to exist, in all its strange and wonderful guises.

In the fall of 2005, New York publisher W.W. Norton republished Darwin's four most important and most widely read books under the title *From So Simple a Beginning.* The volumes in the boxed set are beautiful india-paper editions of the *Voyage of the Beagle* (1845), *The Origin of Species* (1859), *The Descent of Man* (1871), and *The Expression of Emotions in Man and Animals* (1872). The title of the reissue refers to the famous closing sentence of *The Origin of Species*, which we encountered earlier in Chapter 11:

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

According to Edward O. Wilson, who wrote the afterword for the volumes, the effect of the Darwinian revolution in biology went much further than the Copernican revolution in astronomy. Copernicus broke with the idea that the earth is the centre of the universe, an idea that was more than two thousand years old. Rather than being the centre of the cosmos, he showed the earth to be an insignificant satellite of the sun. In his turn, Darwin removed humans from the

centre of the world by showing we are only an insignificant twig, one that appeared only recently among the many branches on the ancient evolutionary tree. In this way, Darwin brought an end to a deeply cherished tenet: the idea that humans were put on this earth with a predetermined plan and a special purpose.

As mentioned earlier, we cannot possibly know all the many implications of the theory of evolution because the revolution is still well underway. During the course of the twenty-first century, the century of biology, the Darwinian paradigm might reach maturity. Only then can we begin to take stock of the situation. At the same time, the theory of evolution will continue to meet with resistance because by no means everyone is willing to embrace this theory and accept the consequences. Religion, which will continue to gain ground, will clash more often and more fiercely with the insights from scientific advances. The gulf between knowledge and faith will become ever wider, and it will become nearly impossible to bridge the differences of opinion. But we should make no compromises, because the Darwinian revolution is unstoppable, unless the zealots get their way and the world is once again shrouded in darkness.

According to Wilson, the Darwinian revolution – even more than the Copernican revolution – broke with the self-image humans had of themselves, which had endured although ancient. Superstition, traditional myths, and divine explanations are often hard to reconcile with tried and tested empirical science. This applies particularly to the theory of evolution, because in the history of humankind, no other idea has more radically changed our self-image. Who are we? Where do we come from? And where are we going? Our ancient ancestors may have also asked themselves these same profound questions as they gazed up from the African savannah at the stars in the clear night sky. Since Darwin, we know who we are and where we come from. Where we are going, only evolution knows – and evolution has the last word.