The Selfish Gene

INTRODUCTION

BRIEF BIOGRAPHY OF RICHARD DAWKINS

Richard Dawkins is a British evolutionary biologist and ethologist, meaning he primarily studies animal behavior. Dawkins was born on March 26, 1941 in Nairobi, which was part of the colony of British Kenya at the time. As a child, Dawkins believed in God because he thought such a complex and diverse natural world must have been designed by a maker, a higher power or intelligence that created it. However, Dawkins became a fervent atheist as a teenager, after he decided that evolution provided a more convincing explanation for the biodiversity of the natural world than religion did. Dawkins studied zoology at Balliol College, Oxford, and completed his graduate education under Nobel-prize winning ethologist Nikolaas Tinbergen, a pioneer in animal behavior research. Dawkins' graduate research centered on understanding how animals make choices. He became famous worldwide after publishing *The Selfish Gene* in 1976 and popularizing the gene-centered view of evolution, in which animal behaviors are seen as primarily being motivated by the goal of preserving and disseminating the animal's genes. The book had a profound impact on scientific research in evolutionary biology, and prompted the establishment of several new fields of research. Dawkins subsequently published *The Extended Phenotype* in 1982, which argues that genes not only manipulate the bodies of organisms, but also the entire world around us. Dawkins has held prestigious academic positions for most of his career, primarily at the University of California at Berkeley and Oxford University. Dawkins is known for his approachable writing style, which favors clarity and non-technical language. Many of his books have become international bestsellers, and *The Selfish Gene* is consistently ranked among the top ten nonfiction works ever written. Dawkins has also become an outspoken critic of religion, in both academic and political contexts. His views on this issue culminated in his1986 book *The Blind Watchmaker*, and more strongly in his 2006 book *The God Delusion*.

HISTORICAL CONTEXT

On December 27th, 1831, young British geologist Charles Darwin embarked on a five-year sea voyage around the world aboard the *HMS Beagle* to collect samples for geological research. The ship sailed from Plymouth, in the south of England, before traveling down the west African coastline to Cape Town, across the Atlantic Ocean, around South America, and on to Australia via the Galapagos Islands of Ecuador. Having witnessed the immense biodiversity of the world on an intercontinental scale, Darwin conceived the theory of evolution, which argues that species evolve (or change over time) due to natural selection, meaning those individual animals most suited to their environment live on to produce subsequent generations. This principle is often referred to as "survival of the fittest." Darwin published his findings in his 1859 book, *On the Origin of Species*. Though immensely controversial and world-shaking in its assertions about the origins of humanity, by 1875 the theory of evolution was widely accepted, and by the 1940s it was considered foundational to the study of life sciences. In 1976, Richard Dawkins published *The Selfish Gene*, in which Dawkins provides a slightly different theory of evolution that focuses on genes, rather than species. This "gene's eye view" of evolution became central to many branches of life science research. Soon after, advances in genetics research prompted the Human Genome Project, which launched in 1990. It was a global research effort to map the entire human genome. The project was finally completed in 2003, after scientists identified the 40,000 genes that make up a human, and sequenced 99.99% of human DNA. The project had a profound impact on human biological research, particularly in the areas of human health and disease.

RELATED LITERARY WORKS

Dawkin's thoughts about evolution and genes are influenced by the work and ideas of many scientists who both preceded him and were his contemporaries. He mentions and describes the thoughts of many of those scientists in *The Selfish Gene*. Perhaps the book with which he most powerfully interacts is Charles Darwin's 1859 book, *On the Origin of Species*, which first laid out the theory of evolution. In *The Selfish Gene*, Dawkins takes Darwin's ideas and applies them not to species, as Darwin did, but to genes. Dawkin further develops some of the ideas in *The Selfish Gene* in his book *The Extended Phenotype*.

KEY FACTS

- **Full Title:** The Selfish Gene
- **When Written:** 1973-1975
- **Where Written:** Oxford, United Kingdom
- **When Published:** 1976
- **Literary Period:** Postmodern
- **Genre:** Nonfiction
- **Setting:** The animal world in nature
- **Climax:** Dawkins suggests that looking at genetic code might unlock countless mysteries of Earth's ancient history. He speculates that perhaps he'll share more insights about this when the 50th anniversary edition of *The Immortal Gene* is

published.

- **Antagonist:** People that believe in group selection
- **Point of View:** First person omniscient

EXTRA CREDIT

Memes. Dawkins is credited with inventing the term "meme" when discussing the spread of cultural ideas in *The Selfish Gene*. A meme (adapted from the Greek word "mimemis," meaning imitation) is a catchy idea that gets copied a lot. Some people joke that it might actually be the word "meme" that is Dawkins' most influential contribution to human culture.

Metaphors. Dawkins is famous for his enthusiastic and approachable writing style, aimed at appealing to the general public and theorists alike. He tends to avoid technical jargon in his explanations, and favors using literary devices like metaphors and personification to make his arguments instead.

PLOT SUMMARY

Richard Dawkins—the author of *The Selfish Gene*—is the sole voice of its story. He believes that evolution happens to genes, not species. He also thinks there is no gene for altruism (selfless or kind behavior). He thinks this is quite a radical view, because it implies that we humans are "lumbering robots," programmed by our genes to help them—the genes—survive. He thinks this is as strange as "science fiction" but it's actually the truth.

In his "Preface to the Second Edition" of *The Selfish Gene*, Dawkins says he is writing for three kinds of people: the general reader (for whom he has avoided technical language), the scientific expert (who might see something in his story that they perhaps overlooked in their more technical way of looking at things), and the student (who might find the book helpful in breaking down technical theories into everyday language).

Dawkins begins (in "Why Are People?") by saying that Charles Darwin offered the first coherent account of why we are here—why we exist—when he formulated the theory of evolution in *On the Origin of Species*. Evolutionists claim that the world's biodiversity exists because the natural world became more complex over time (evolved) through small changes in the way organisms interacted with their environments (adaptations). Since organisms were competing for finite resources (such as food), those individual organisms best suited to their environments won out and survived to reproduce, passing their traits on to succeeding generations. This process is called natural selection. Darwin also calls it "survival of the fittest." Dawkins, though, thinks that genes (and not species) are evolving through natural selection. He actually thinks if Darwin were alive long enough to know about genes, Darwin would think this too. Dawkins decides to offer an account of life on earth from the "gene's perspective" to explain his view.

Dawkins starts at the beginning: in the earliest time in history, when our universe was "simplicity." This is how he opens his second chapter, "Replicators." He explains that the ancestors of our genes were created by accident when the first atoms latched together into molecules that could make copies of themselves by attracting atoms to connect in the same patterns. These molecules were the first replicators. Sometimes, copies produced by replicators are a little bit off. As a result, different replicators emerged that were competing for atoms. This set up the conditions for evolution to occur.

In the subsequent two chapters ("Immortal Coils and "The Gene Machine"), Dawkins explains that all living organisms, from single cells to humans, are effectively "**survival machines**" created by genes to protect themselves (or, to protect their atoms from being stolen by other replicators). This means that organisms exist because they keep genes alive, as copies of themselves, from generation to generation. Hypothetically, this process could go on forever, and so genes are technically immortal.

Over the next six chapters, Dawkins addresses selfishness and altruism in nature. First, Dawkins discusses aggression in animals, in a chapter aptly called "Aggression." He thinks that when animals refrain from being aggressive, they're not actually being altruistic. Rather, those behaviors increase the animal's chance of surviving to reproduce and, therefore, to keep the animal's genes in the gene pool. For example, a small animal is unlikely to win a fight with a large predator, and so its tendency to flee when it sees a large predator will keep it alive, and when that small animal reproduces its tendency to flee instead of fight will get passed on in the gene pool.

Dawkins moves on to discuss cooperation and conflict among family members in his chapters entitled "Genesmanship," "Family Planning," and "Battle of the Generations." He argues that animals are mostly nice (but sometimes nasty) to their relatives because relatives share genes. Cooperation among "kin" makes shared genes more numerous in the gene pool overall. For example, when a bird gives his baby brother a share of his food, he is actually helping to keep his own genes alive. Those genes just happen to live in his brother's body. Sometimes, it pays off to be "nasty" and preserve the genes in your own body. But sometimes, it pays more to be "nice" to your relatives, because it preserves those same genes in their bodies. Dawkins looks at the work of various researchers to argue that altruism among family members is roughly proportional to the genetic relatedness between two individuals. In this way, all altruistic behavior between relatives actually betrays "selfish" genes working behind the scenes to ensure their own survival.

Dawkins repeatedly stresses that genes aren't actively choosing to be "selfish," since genes aren't conscious. Rather, genes provide instructions for building embryos, like "build an embryo that will have long legs" (this helps organisms run faster and escape from predators), or "build an embryo that will chirp when there's food nearby" (this benefits a chick's nearby genetic relatives). These behavioral traits are a blind gamble: they're the result of genes randomly shuffling in and out of chromosomes in sex cells. If the resulting behavioral traits happen to keep the organism alive long enough to reproduce, the gene for that trait will be passed on.

In the next two chapters, entitled "Battle of the Sexes" and "You Scratch My Back, I'll Ride on Yours," Dawkins discusses mating, sex ratios, social insects (such as ants and bees), and cooperation between unrelated individuals. In each case, Dawkins tries to show that behavioral traits exist in nature because they enable genes to pass on from generation to generation. Dawkins uses a hypothetical scenario called The Prisoner's Dilemma from game theory (which is the mathematics of strategic behavior) to show that when two individuals are interacting, those that survive to reproduce tend to help each other out at first, but won't help again if the favor is not reciprocated. This means cooperation happens because it increases the individual's chances of survival, which is a "selfish" motivation.

Group selectionists offer alternative explanations for all the behaviors Dawkins discusses in these six chapters. Group selectionists tend to assume that altruistic behavior in nature—evidenced by birds that pick parasites off each other's backs, and "kamikaze" bees that die when they sting—exists so that the group as a whole has a better chance of survival. Dawkins' goal is to dismantle this view, by showing that all seemingly altruistic behavior is really selfish behavior when it's looked at from the "gene's eye view."

Dawkins then switches tracks to talk about human culture in his next chapter, "Memes: The New Replicators." He thinks that humans are different from most other organisms on earth because there are two kinds of evolution that affect human behavior. The first, as with all other organisms, is genetic evolution. The second is cultural evolution. Dawkins thinks cultural evolution happens through "memes." Memes are things like ideas, catchy tunes, memorable images, and fashion trends that spread in a culture when they become numerous, by existing in different people's brains. Memes compete with each other to be remembered and shared. A brain's capacity for memory is finite, which sets up the conditions for evolution. The replicator in this kind of evolution is the meme. Memes are different from genes because they evolve much, much faster than genes do. This is why an English-speaking person today would have a hard time understanding the writings Geoffrey Chaucer (who wrote in English in the fourteenth century). Dawkins thinks that the concept of altruism comes from a meme, and not from a gene.

In his penultimate chapter, entitled "Nice Guys Finish First," Dawkins revisits the topic of mutual cooperation to explore it more fully. He believes that all forms of strategic interaction in nature are versions of The Prisoner's Dilemma in action. He stresses again that reciprocal altruism (or being "nice") only exists when it increases a gene's chances of survival.

The final chapter of *The Selfish Gene*, called "The Long Reach of the Gene" summarizes Dawkins arguments from another book of his called "*The Extended Phenotype.*" Dawkins thinks that genes bundle together as colonies or "cartels" that live in discrete bodies because this cooperation is more effective at keeping them alive. He also thinks that genes perpetuate themselves through the "bottleneck" process of sexual reproduction because it's easier for evolution to happen when each generation starts anew from a single cell. If that single cell has a mutated gene in it, it automatically spreads to every cell in that organism. It's no surprise, he says, that biologists initially got confused. When they started looking around, they saw organisms that reproduce, so they mistakenly assumed that either organisms or species of organisms were the things evolving. Although when you really think about it, Dawkins says, the boundaries of an "individual" are somewhat arbitrary. Some genes affect behaviors in other organism's bodies (this happens when a parasite's genes manipulate the body of its host). Some genes affect behaviors in the environment at large. This happens when organisms modify their environment and increase their chances of survival, for instance by building dams or nests. Dawkins thinks all of these examples are phenotypic effects. He thinks we tend to talk about individuals evolving in the context of their environments, but really, we should be talking about genes evolving in the context of their phenotypic effects.

Dawkins ends *The Selfish Gene* with an "Epilogue to the 40th Anniversary Edition." In the epilogue, he argues that he hasn't only been telling a story about genes. He's also been telling a story about replicators. His story about genes in nature is just one example of a story about a replicator that evolves. His story about memes in a culture is another example of a replicator that evolves. There are likely many more stories to be told. He is certain, however, that every story about evolution—even on other planets—is a story about a replicator. In closing, Dawkins recalls that genes are technically immortal. This means that written in our genetic code is the history of life on earth, waiting to be decoded. He wonders what we could learn about dinosaurs or the origins of the universe if we were to start decoding the information in our genes. Perhaps, Dawkins says, he'll work on that next, and share his insights when the 50th anniversary edition of *The Selfish Gene* is published.

CHARACTERS

MAJOR CHARACTERS

Richard Dawkins – A scientist who is the author and sole voice of *The Selfish Gene*. He is inspired by Darwin's theory of evolution, but offers a different perspective on the topic. He believes that genes functioning to ensure their survival are at the root of evolutionary processes, and uses the metaphor of the "selfish" gene to capture this. This means there is no gene for altruism. To explain this view, he looks at a wide range of anima behaviors from the "gene's eye view." He focuses on birds, but also addresses other animals, plants, insects, parasites, bacteria, people, and even human culture. Along the way he discusses the views of various other scientists and thinkers. Dawkins agrees with Maynard Smith, Hamilton, Trivers, Fisher, and Williams, who also endorse the "gene's eye view" of evolution. Dawkins disagrees with Lorenz and Wynne-Edwards, because they believe evolution happens to groups (or species), and not genes. Dawkins often uses metaphors and personification rather than technical scientific language, and his voice is distinctive in reflecting his personal enthusiasm for this topic.

Charles Darwin – A geologist who developed the theory of evolution in the 1800s after taking a five-year sea voyage around the world and publishing *The Origin of Species*. Darwin argues that the biodiversity of the natural world is explained by natural selection, meaning organisms that are better adapted to their natural environments survive to reproduce and pass on their traits, which explains how species change over time. This view became central to life sciences research in the 1940s. People who follow this view are considered "Darwinian." Dawkins is highly inspired by Darwin's theory, though he thinks it hasn't been taken seriously enough in the scientific world. Dawkins expands on Darwin's view, but reframes evolution as something that happens to genes, rather than species.

John Maynard Smith – A mathematician and scientist. His views about evolution make a profound impact on Dawkins, who leverages Maynard Smith's ideas often to support his own argument. Maynard Smith believes, like Dawkins, Trivers, Williams, Fisher, and Hamilton, that evolution happens to genes, and not species. Dawkins references Maynard Smith when discussing evolutionarily stable strategies and behavior strategies in risky situations (also known as "game theory").

William (Bill) D. Hamilton – A biologist who believes, like Dawkins, Maynard Smith, Trivers, Fisher, and Williams, that evolution happens to genes, and not species. Dawkins borrows from Hamilton, the rhetorical device of personifying the gene to explain its behavior. Both scientists imagine that genes act as if on purpose, meaning genes can be described with metaphors like "selfish" or "cooperating," when in reality genes are not conscious in that way. This rhetorical device enables Dawkins to explain evolution from a hypothetical "gene's eye view." Dawkins also borrows Hamilton's method of calculating the genetic relatedness between two individuals.

Konrad Lorenz – One of Dawkins's scientific rivals in *The Selfish Gene*. Lorenz, like Wilson and Wynne-Edwards, argues that sometimes an animal might sacrifice themselves for the benefit of the group or species. This view is called "group selection," meaning that evolution happens on the group or species level. Dawkins thinks that Lorenz is wrong, and spends a lot of time showing why he believes the "group selection" theorists are incorrect.

MINOR CHARACTERS

George C. Williams – A biologist who believes, like Dawkins, Trivers, Maynard Smith, and Hamilton, that evolution happens to genes, and not species. Dawkins uses Williams' concept of what a gene to get his argument going.

Robert (Bob) Trivers – A mathematician and scientist who believes, like Dawkins, Maynard Smith, Williams, Fisher, and Hamilton, that evolution happens to genes, and not species. Dawkins references Trivers when discussing behavior strategies (also known as game theory), especially among families. Trivers works with Hare on formulating these strategies.

Robert Axelrod – A scientist who works on animal behavior using game theory (the mathematics of predicting behavior). Dawkins discusses Axelrod when discussing behavior strategies like cooperation.

V. C. Wynne-Edwards – A scientist who, like Lorenz and Wilson, believes in group selection, and was one of its earliest advocates. Dawkins thinks Wynne-Edward's view is mistaken.

E. O. Wilson – A scientist who, like Lorenz and Wynne-Edwards believes in group selection. Dawkins thinks Wilson's view is mistaken.

R. D. Alexander – A scientist of animal behavior. Dawkins discusses Alexander when addressing parent-child relationships.

David Lack – A scientist who does research on clutch sizes in birds.

A. Zahavi – An evolutionary biologist. Dawkins discusses Zahavi when addressing bluffing. Dawkins disagrees with a lot of Zahavi's explanations.

R. A. Fisher – A scientist who, like Dawkins, Maynard Smith, Hamilton, and Trivers, endorses the "gene's eye view" of evolution. Dawkins discusses Fisher when discussing sex ratios in animal populations.

R. Ardrey – A scientist who believes there is altruism in nature.

H. Hare – A theorist who works with Trivers on behavior strategies.

Geoffrey Chaucer – A playwright who was alive in medieval England. Dawkins thinks that Chaucer's English was very different to the English we speak nowadays, which shows that language evolves.

P. F. Jenkins – A scientist who studied the evolution of saddleback bird songs in New Zealand. He thinks that saddleback bird songs are an example of cultural evolution.

Sir Karl Popper – A theorist who thinks that culture evolves.

L. L. Cavalli-Sforza – A geneticist who thinks that culture evolves.

T. F. Cloak – An anthropologist who thinks that culture evolves.

J. M. Cullen – An ethologist who thinks that culture evolves.

Socrates – An ancient philosopher.

Leonardo – A historical artist.

Copernicus – A scientist.

G. S. Wilkinson – A scientist who conducts research on vampire bats. Dawkins mentions Wilkinson when discussing behavior strategies between individuals that are not closely related.

James Crow – A geneticist.

Queen Elizabeth II – Dawkins's 15th cousin, twice removed.

Yan Wong – A scientist who is working with Dawkins on uncovering information about humankind's ancient past based on genetic code.

TERMS

Natural Selection – Natural selection is the process by which evolution happens. Evolution occurs when entities compete for finite resources in an environment. The entities that succeed in getting the resources are the ones that are the "fittest" (or most effective at competing) in that environment, and the ones which are then able to reproduce. **Charles Darwin** considers natural selection to be process of "survival of the fittest." Although many theorists assume that natural selection is a process that happens to species of organisms, **Richard Dawkins** thinks that natural selection actually happens to genes. Later in his argument, Dawkins extends the scope of natural selection to argue that it also explains how ideas (or memes) are perpetuated in a cultural environment.

Replicator – A replicator is any entity that can make copies of itself. **Richard Dawkins** argues that, in the natural world, the replicator is not the organism or the species, but, rather, little bits of DNA called genes. Dawkins argues that ideas, or memes, are also replicators, because their copies embed themselves in different people's brains. Theoretically, a replicator can be any entity that is capable of making copies of itself. A replicator isn't defined by what it's made of, but by its function, which is making copies or clones of itself. For Dawkins, the replicator is the thing that is evolving in any form of evolution.

Evolutionarily Stable Strategy/State (ESS) – An evolutionarily stable strategy, or an evolutionarily stable state (both of which are abbreviated to "ESS"), exists when the entities that are competing in an environment stay in stable ratios from generation to generation. In the natural world, an evolutionarily stable strategy arises when organisms behave in such a way that their genes stay in the same proportions from generation to generation. In the molecular world, an evolutionarily stable state arises when molecules form that tend to stay connected (or "stable") over time. Evolutionarily stable strategies and states are difficult to disrupt. When they are disrupted, the ratio of different kinds of genes swings back and forth like a pendulum until it settles on a new balance that stays that way from generation to generation. This is what happens when "a little bit of evolution" occurs. The concept was invented by **John Maynard Smith**, and is used by **Richard Dawkins** to explain genetic evolution.

Parental Investment (PI) – Parental investment is derived from the total amount of resources that an organism has available to use on keeping its offspring alive over the course of the parent's lifetime. It represents any resource (such as energy, time, food, or labor, to name a few) that increases an offspring's chance of survival at the expense of another existing or potential future offspring. As a result, offspring compete with each other for parental investment. For example, the parental investment in a glass of milk is measured by the amount that one offspring's drinking the pint of milk reduces the life expectancy of any of that offspring's current (or potential future) siblings. The concept of parental investment was formulated by **Robert Trivers**. Richard Dawkins uses the concept at length to explain behavior between related individuals, especially parents and their offspring.

Prisoner's Dilemma – The Prisoner's Dilemma is a hypothetical puzzle from game theory, which is the mathematics of predicting behavioral strategies. The Prisoner's Dilemma gets its name from a thought experiment in which there are two prisoners who have been separated into different jail cells. The police are trying to get the prisoners to confess to a serious joint crime (say, shooting someone). Neither prisoner knows what the other one is saying to the police. If neither prisoner confesses, they get short jail time for a milder crime (say, a month in prison for firearms possession). If both confess, they each get short jail times for the serious crime, with early parole for telling the truth (say, a year in prison). But if one confesses while the other stays silent, then the one who confesses is set free, while the one who doesn't confess goes to jail for a long time (say, five years). In other words, the prisoners can get the best possible outcome for their group of two if each refuses to betray the other and they both remain silent. However, each prisoner can get the best odds of being set free by betraying the other and confessing. The Prisoner's Dilemma shows that when two individuals are interacting, it's usually more logical and beneficial for each individual to act in a way that is selfish rather than altruistic, because there is less risk in acting selfishly. **Richard Dawkins** believes that interactions in nature are essentially versions of the Prisoner's Dilemma. He uses this concept to explain that mutual cooperation happens in nature when it reduces the chance of a bad outcome (such as death) in the future, but also why selfishness is the more likely explanation for behavior.

Phenotypic Effect – Genes are instructions for building embryos. In large part, an embryo looks and acts the way it does because of its genetic programming. The observable effects of a gene in nature are its "phenotypic effects." People can't see genes, but they can see phenotypic effects. **Richard Dawkins** thinks that the phenotypic effects of a gene are not limited to the embryo they build, but to the environment at large. In this view, any aspect of an environment that affects the chance of a gene's survival is a phenotypic effect. For instance, Dawkins thinks that beaver dams, snail shells, and sneezing from a cold virus are all phenotypic effects. He uses this argument to dismantle the notion of an individual organism as something discrete and separate from other things in nature.

Meme – A meme is a catchy idea that circulates in a culture. **Richard Dawkins** coins the word "meme" by adapting it from the Greek word *mimeme*, which means "imitate." He thinks memes jump from brain to brain, by being copied into different people's minds. For example, a scientist might learn about an idea from a paper. If the scientist likes the idea, they'll talk about it in their lectures, and their students will learn about the idea as well. The scientist will likely also talk about the idea with their peers, and maybe mention it in their papers, meaning more people will learn about the idea and store a "copy" of the idea in their brains. According to Dawkins, a meme is a replicator. Since each brain has a limited capacity for memory, memes essentially compete to be remembered, in a new form of evolution: cultural evolution. Some examples of memes include the idea of God, a catchy tune or jingle, a memorable image, or—importantly—the idea of altruism. Dawkins argues that altruism doesn't exist in nature, so it must be an idea that was invented at some point, and then spread in human culture.

THEMES

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THE GENE'S EYE VIEW OF EVOLUTION

The Selfish Gene offers an account of evolution from the perspective of genes. Darwinian evolution (as defined in Charles Darwin's 1859 book *On the Origin of the Species*) claims that life on earth evolved from simpler organisms through natural selection. According to Darwin, natural selection favors organisms that are slightly better adapted to their natural environment, and therefore more likely to survive and reproduce, which results in those organisms passing on their traits to succeeding generations. Richard Dawkins argues that since hereditary traits are passed on through genes, it actually makes more sense to think of *genes* as the units that evolve. But this view raises a question about why organisms (like humans, cells, plants, and animals) need to exist at all. Dawkins argues that organisms exist and reproduce in the way that they do because this provides an evolutionary advantage for the genes that exist inside of them.

Dawkins tells the story of the origin of life on Earth from the "gene's eye view," to explain that organisms developed out of "simplicity" through the mechanism of gene-based evolution. As Dawkins describes it, at the start of the universe, there were just atoms floating around in energy. Dawkins calls this state a "**primordial soup**." Eventually, atoms started clumping together to create molecules. At some point, one of these patterns resulted in molecules that attracted around them to form similar patterns. This process of attraction is a sort of "replication." The molecule essentially creates a "copy" or "clone" of itself with other atoms that are still floating around. "Replicating" molecules, according to Dawkins, are the ancestors of DNA. Replication must have been an imperfect process, meaning some "copies" would have slightly different arrangements of molecules. In a universe with finite atoms, all the slightly different molecules would have to compete for free atoms in order to replicate. Eventually, one particular arrangement of atoms must have created a molecule that was able to build "protein" around itself, thereby protecting its atoms from being stolen. These were the first cells. Eventually, it must have been the case that cells that clumped together were better at protecting their replicating components. These clumps of cells were the first organisms. This is how cells containing DNA eventually formed into organisms over the course of thousands of million years.

Dawkins then argues that genes (or, DNA)—and not organisms—are the things that are evolving. After all, before organisms could exist, genetic code with the instructions to build organisms had to exist, and genetic code is still around. In fact, it's genetic code—the "the unit of heredity"—that gets passed on through the processes of reproduction. Organisms, in this view, are simply "machines" that house genes. Organisms exist because they help genes survive. As Dawkins writes "[we] are all **survival machines** for the same kind of replicator—molecules called DNA—but there are many different ways of making a living in the world, and the replicators have built a vast range of machines to exploit them. A monkey is a machine that preserves genes up trees, a fish is a machine that preserves genes in the water. There is even a small worm that preserves genes in German beer mats. DNA works in mysterious ways."

The "gene's eye view" of evolution, thus, argues that life on earth exists in the way it does because genes are competing to survive, and the genes that win out through natural selection must be those that lay out the "blueprints" for creating organisms as we know them. These organisms—including humans—are "survival machines" for the genes they contain.

SELFISHNESS, ALTRUISM, AND COOPERATION

One of Dawkins' central motivations in *The Selfish Gene* is "to understand the biology of selfishness and altruism." Some animals sacrifice themselves so that other animals in their species can survive. There is also apparent evidence of cooperation in nature, both between species and between genes. Dawkins argues, however, that when these behaviors are looked at from a genetic perspective, they only *appear* to be altruistic, and that cooperation only occurs when there is an evolutionary advantage to cooperating. In fact, Dawkins argues that cooperative behaviors always ensure the genes' survival, and that genes are fundamentally "selfish" and altruism in nature is an illusion.

Historically, biologists assumed that some organisms act selflessly in order to ensure the species as a whole survives. They assumed that the "unit" that evolves wasn't the individual animal, but the species as a whole. Dawkins argues that "groups" cannot be the units that evolve, because animals tend to favor their own kin (who are their genetic relatives) over others in the group (who are not). Birds, for example, expose themselves to predators to gather food for chicks, but they usually only feed the chicks in their own nests. Technically, if the thing that matters is the survival of the group, there is no evolutionary reason for a parent to favor its own chicks over others in the species. From the genetic perspective, however, this behavior makes perfect sense. A parent's child contains copies of the parent's genes, while other children in the species do not, so parents focus on the survival of their own offspring.

Dawkins also argues that cooperation between species only exists when it results in an "evolutionarily stable strategy" (or "ESS"), meaning it enables the gene's survival in the long run. Essentially, if we logically work through the potential outcomes of "selfish" behaviors between species, it turns out that, in these instances, genes that are able to create cooperating organisms are most likely to survive. Pregnant fig wasps, for example, lay their eggs in figs. The young wasps then take nourishment from the figs as they grow, while at the same time transferring pollen between fig trees, facilitating tree reproduction. Fig wasps *could* lay more eggs, but then the fig trees would lose too many resources nourishing the extra wasps, and die. The wasps would lose their source of nourishment. So, genes that instructed wasps to lay as many eggs as possible didn't survive in the long run because laying so many eggs isn't an "evolutionarily stable strategy." Similarly, fig trees could bear fruit that larval wasps can't survive in. But the genes that instructed fig trees to do so most likely died out when wasps didn't survive to transfer their pollen. This genetic strategy too, isn't "evolutionarily stable." In the long run, genes that instructed wasps to lay some (but not too many eggs), and genes that instructed fig trees to bear wasp-nourishing figs would have the greatest overall chance of survival. Fig wasps and fig trees thus appear to "cooperate," but this is only because cooperation keeps their respective genes alive.

A third instance of apparent cooperation happens within organisms, between genes. An organism is technically a "colony" of many different genes cooperating with each other to ensure the survival of all the genes in the organism. Dawkins argues, though, that genetic cooperation only occurs when it gives individual genes an evolutionary advantage. Completely selfless genes would give up resources that they need to replicate. But then they wouldn't be able to replicate, so they would die out. On the other hand, completely selfish genes would steal resources that other genes need to replicate. But then the organism that houses them all would die, and those genes would die too. In the long run, genes that cooperate just enough to keep their "survival machines" alive win out, since those survival machines live to reproduce and pass on those genes. Genetic cooperation thus only happens when it better enables a gene to survive.

Dawkins argues that from the genetic perspective, cases of apparent altruism, cooperation between species, and genetic cooperation always hide a "selfish" gene working behind the scenes to ensure its own survival. In other words, Dawkins argues that, technically, there is no such thing as altruism in nature. Dawkins thus concludes that if humans want other humans to behave altruistically toward each other, this behavior has to be learned: it can't be inherited.

CULTURE AND MEMES

Dawkins argues that even though humans are simply "survival machines" that house genes, there is still something that makes humans different from all the other types of "survival machines" that contain genes (such as flowers, seagulls, or elephants). The difference is that there are two kinds of evolution going on in the case of humans. One kind of evolution is the same as in every other living thing on earth, and it's the evolution of genes. But the second kind of evolution that happens when humans are in the picture is the evolution that happens to bits of human culture. This cultural evolution is what makes humans "exceptional."

Language, for example evolves over time, as made clear by the fact that it's harder to understand "English" written by the 14th century writer Geoffrey Chaucer than it is to understand "English" words that a modern writer might use. In this argument about cultural evolution, ideas, or "memes"—meaning ideas that spread easily from one person to another—are the things "replicating." Dawkins argues that these ideas—or memes—are, in a sense, "copied" from one person's mind to another, but sometimes slightly imperfectly. Dawkins writes: "Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches. Just as genes propagate themselves in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation." For example, if a scientist hears a good theory, they will talk about it with their students, write about it in their academic papers, and discuss it with their colleagues. The "copies" of the meme that arise (in students' minds, in people's minds who read academic papers, and in colleagues' minds) can then be shared with other minds. If an imperfect copy of the original meme is more memorable, or has a stronger "psychological appeal," then that variant of the meme is the one that will survive to be shared with another mind.

Like genes, memes live much longer than people do. This is why ideas that Socrates thought about some two thousand years ago are still going strong. One difference between memes and genes, however, is that memes replicate much faster than genes do. In fact, it would take millions of years to observe the same amount of evolution in genes that a mere century of cultural evolution can expose. Dawkins argues this cultural kind of evolution (and its speed) provides a viable avenue to facilitate altruistic behavior in humans: not through biology, but through the spread of the idea—or meme—of altruism. "Our genes may be selfish" Dawkins writes, "but we are not necessarily compelled to obey them all our lives."

Ultimately, since humans are compelled by our thinking—our ideas—as well as our biology, the story of the evolution on humanity is incomplete without both. In other words, humans should not feel bad that, biologically, we are merely "**survival machines**" for genes, because there is something that makes humans "exceptional." That thing is humanity's capacity to generate rapidly evolving ideas (or memes). This is what enables us—unlike other organisms—to extend beyond the blind programming of our genes, and choose to behave in ways we are not genetically programmed to.

THE UNIT OF EVOLUTION

In the "epilogue" to his second edition of *The Selfish Gene*, Richard Dawkins claims his argument—that genes, and not organisms evolve—is still true even if there's no agreement about what bits of biological material exactly comprise a "gene." In fact, Dawkins claims that his account explains evolutionary processes regardless of what thing is evolving, whether these things are "genes" or something else. Ultimately, Dawkins says that his argument is more about "replicators" and their necessity for evolutionary processes, than about genes themselves. The replicator argument includes the gene's story, but it also says things about entities that are not genes.

A "gene," for Dawkins, is simply some "thing" that performs the function of "replicating" itself, or copying itself, in order to keep existing. This "thing" is just a type of "replicator." Dawkins states that because his argument pertains to replicators in general rather than to genes in particular, it can successfully explain the evolution of ideas in a culture just as easily as it explains the evolution of genes in life on Earth. In fact, Dawkins thinks his account can even explain the evolution of life on other planets. Dawkins writes, "The Selfish Gene is quite likely a valid account of life on other planets even if the genes on those other planets have no connection with DNA."

This type of explanation in science (called functionalism) focuses on explaining things based on the functions they perform, rather than the stuff they're made up of. For Dawkins, evolution is not possible without something (whatever that thing is) that makes imperfect copies of itself, such that the copies then compete for finite resources, with the slightly better imperfect copies winning out to make more copies. As long as the "things" perform the function—whether the thing is a strand of DNA or an idea—it can be explained by the theory. To offer an account of cultural evolution, Dawkins doesn't have to change his theory of the "selfish gene"—instead, he just plugs in the components that replicate. In culture, these components are "memes" or ideas. Dawkins writes "But is there anything that must be true of all life, wherever it is found, and whatever the basis of its chemistry?... If I had to bet, I would put my money on one fundamental principle. This is the law that all life evolves by the differential survival of replicating entities."

Dawkins' argument is therefore broader than his argument about genes. It is really an argument about replicators, of which genes are just one example. When faced with the task of trying to figure out the story of something that evolves, Dawkins concludes—whether it's life on earth, or artificial intelligence, or ideas in a culture, or alien life—look for the replicator, and you will find the "unit" that is evolving.

SYMBOLS

Symbols appear in **teal text** throughout the Summary and Analysis sections of this LitChart.

SURVIVAL MACHINES

Survival machines represent all the different organisms in the world. Every living being is a survival machine, including cells, viruses, algae, parasites, beetles, mice, whales, humans, and everything in between. Dawkins calls living things survival machines because he believes that organisms are built by genes for the sole purpose of facilitating those gene's survival. Genes, as Dawkins defines them, are small bits of DNA that can clone themselves. Cells are a group of genes that has built a protective wall around itself by synthesizing protein. The protective wall keeps the genes safe from invasion by other molecules. A cell, therefore, is a very simple example of a "machine" that helps DNA—or, genes—stay intact, or "survive." Dawkins thinks that over time, genes built more and more complex and efficient machines to protect its molecules, and that's what all the organisms on earth are. This viewpoint supports the argument that all living things are just "machines" programmed by genes to help the genes "survive." Dawkins thinks this is a profound claim, because it means that genes (and not organisms) are the things that are evolving in this world. Humans, in a sense, like all organisms, are just by-products of this process.

PRIMEVAL SOUP

Primeval soup is an environment in which very simple replicators have formed. In the natural world, primeval soup is the simplicity of the universe in its very early stages, when it would have just been a bunch of atoms floating around in space. In the cultural world, primeval soup describes ideas floating around in consciousness. Importantly, just like an actual bowl of soup, there's a finite amount of primeval soup. As a result, the components of the soup are competing for finite resources. This condition is important because the scarcity of resources create the requirement for competition that is necessary for evolution to occur at all. In nature, some atoms combined into molecules that could make copies of themselves by attracting other atoms to latch onto them in the same patterns (these are replicators, and the ancestors of DNA). Once in a while, a copy was slightly off, which meant that two slightly different replicators were competing for the limited atoms in the "soup." If one of the slightly-wrong copies was better at getting atoms to latch onto it, it would use up all the atoms floating around in the "primeval soup," and then take atoms from other replicators. Effectively, a better replicator will have replaced a slightly worse one. This process is evolution. Importantly, Dawkins thinks evolution can only occur in an environment where replicators compete for finite resources (or, in primeval soup). He argues on this basis that genes (little bits of DNA) are the things evolving, and not species.

ARCHITECT'S PLANS

Just as an architect's plans give instructions for how to make a building, genes give instructions for how to build an embryo. Dawkins uses the metaphor of architect's plans to explain how genes are distributed in the body of an organism. Imagine there is a building with a bookcase in every room. Each bookcase contains binders full of loose pages. The pages contain instructions for how to build the house the binders are in. Every bookcase in the building (or cell in the body) contains binders (chromosomes) containing pages which list the full set of instructions for building a copy of that building (genes). Just as architect's plans are responsible for why a building looks the way it does, genes are responsible for why organisms look and behave the way they do. The only difference is that in the genetic picture, there is no "architect." The pages are shuffled together at random. This means if they are a good combination of instructions, they'll produce an organism that won't die (or a house that won't fall down). Dawkins is keen to stress this point because he often talks as if genes are conscious, making choices, and acting selfishly and so on. But in actual fact, he means that genes have effects on how organisms look and act, and they survive if those effects keep organisms alive, but none of this is done on purpose. In this sense, the only "architect" in nature is chance.

OARSMEN

Dawkins uses the analogy of oarsmen to explain that a gene only cooperates with other genes when cooperation increases the chances of its survival. In the analogy, oarsmen (or rowers) are individual genes. A rowboat is the body of an organism. Each oarsman needs several teammates to fill a rowboat in order to so that he can win the race. Each oarsman is selfish, because he wants to win the race. But, likely, his chances of winning the race are increased when his teammates are a good fit with him. For example, it helps if they all speak the same language. It also helps if four oarsmen are right-handed and four are left-handed. Dawkins' metaphor makes clear that just as oarsmen sharing rowboat cooperate to win a race, genes sharing a body collaborate to ensure the body's survival. It's significant, though, that each oarsman cooperates not in order to help the other genes, but for much more selfish reasons: he wants to win the race. Dawkins uses this analogy to show how examples of cooperation in nature can mask selfish motivations. He thinks that every example of cooperative behavior is motivated by a gene interested in its own survival, just as every example of cooperation in the rowboat is motivated by an oarsman interested in winning the race.

ANDROMEDANS

Dawkins uses the metaphor of a fictional alien race called "Andromedans" to explain how genes control the bodies of organisms. Andromedans are aliens who want to control planet earth. Unfortunately, they live very far away from earth. So far, in fact, that if they send a message to earth, they would be long dead before a response comes back. Instead of a message, they decide to send instructions for building a computer. When those instructions finally reach earth, humans decode them and build the computer, which controls earth. In the metaphor, the computer stands for an organism's brain. Genes control organisms in the same sense that the Andromedans can be thought of as controlling earth. Similarly, genes don't control organisms directly, the way that a puppeteer controls a puppet. Instead, genes act by containing instructions for building brains, and these brains then govern the organisms' behavior in a way that is beneficial to the genes.

In this metaphor, both the Andromedans and the instructions they send out are analogous to genes. This point matters to Dawkins because he wants to argue that genes (and not organisms or species) evolve. In order to make his view convincing, he needs a plausible account of why brains exist, since we normally take brains, and not genes, as the powerhouses of our agency.

QUOTES

Note: all page numbers for the quotes below refer to the Oxford University Press edition of *The Selfish Gene* published in 2016.

Preface Quotes

We are survival machines—robot vehicles blindly programmed to preserve selfish molecules known as genes.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Related Symbols:

Page Number: xxix

Explanation and Analysis

Richard Dawkins begins *The Selfish Gene* with this bold claim, which he will spend the rest of the book defending. He alludes to two important ideas that come up time and time again throughout his argument.

Firstly, human beings are "survival machines." Although humans think of ourselves as fully-fledged, autonomous individuals, the only reason we—and every other living thing on the planet—exist is because we were created by genes living inside us, for the sole purpose of perpetuating those genes' existence. Genes are DNA molecules that can make clones or copies of themselves by attracting other molecules to attach to them in the same patterns. Since there is a finite amount of matter in the universe, genes are competing for this matter. In order to protect their own molecules from being stolen, genes build protective shells around themselves made of protein. These protective shells are "survival machines," meaning organism that function for the sole purpose of continuing to exist. Every living thing on Earth is a survival machine that is programmed to function the way it does by genes living inside it. Some of these machines, like humans and birds, are very complex. Others, like bacteria and algae, are very simple. But ultimately, all beings serve the same function: they enable genes to keep existing.

Secondly, a gene only exists if it is able to keep making copies of itself. These copies get passed on through sexual reproduction, and spread into new survival machines with each generation. Since a gene's sole purpose is to keep existing by making as many copies of itself as possible, genes are fundamentally "selfish."

Chapter 1 Quotes

I shall argue that a predominant quality to be expected in a successful gene is ruthless selfishness. This gene selfishness will usually give rise to selfishness in individual behavior. However, as we shall see, there are special circumstances in which a gene can achieve its own selfish goals best by fostering a limited form of altruism at the level of individual animals.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 3

Explanation and Analysis

At the outset of his argument, Richard Dawkins characterizes genes as "selfish." Now, he explains why it matters that genes are selfish. Genes are molecules that contain instructions for building embryos. The sole purpose of a gene is to keep existing, via new embryos created through sexual reproduction. These embryos turn into individuals that act in certain ways on the basis of their genetic programming–so, in a sense, genes continue to live on whenever they're passed on to subsequent generations.

Whereas some scientists believe that species will act altruistically in order to ensure that their genes survive and evolve on a group level, Dawkins believes that individuals only act in ways that *seem* altruistic on the surface. However, the root cause of this observed altruism is always a gene, which designed an individual to act that way so that it could survive, reproduce, and make more individuals containing that gene. In other words, individuals only act altruistic because such behavior helps genes survive: the gene's motivation is inherently selfish.

I shall argue that the fundamental unit of selection, and therefore of self-interest, is not the species, nor the group, nor even, strictly, the individual. It is the gene, the unit of heredity.

Related Characters: Richard Dawkins (speaker), Charles Darwin, E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Page Number: 14

Explanation and Analysis

Many scientists believe that altruism (kindness, or selflessness) exists in nature. They often see animals sacrifice themselves to help other animals. Mammals care for their children. Animals pick parasites off each other's backs. Birds sound alarm calls to others when there's a predator nearby, even if that makes the predator notice them more. Bees even kill themselves when they sting. The list goes on. Scientists like Konrad Lorenz, V. C. Wynne-Edwards, and E. O. Wilson explain these behaviors by suggesting that altruistic sacrifices help the group as a whole survive. Even if the individual dies, their species lives on. This explanation prompts them to argue that groups—or species—and not individuals evolve over time. Such scientists are collectively called "group selectionists."

Dawkins believes that the group selectionist view of evolution is completely mistaken. In fact, he thinks group selectionists have spent so time trying to decide whether individuals or species evolve that they have overlooked the thing that actually does evolve: the gene, the basis of all life on Earth. Dawkins also believes that the "unit" of natural selection (the thing that's evolving) is—by definition—fundamentally interested in its own survival, and therefore a unit of "self-interest." Dawkins thinks that group selectionists make too much of altruism, which overlooks the essential relationship between survival of the fittest and self-interest.

Chapter 2 Quotes

They are in you and in me; they created us, body and mind; and their preservation is the ultimate rationale for our existence. They have come a long way, those replicators. Now they go by the name of genes, and we are their survival machines.

Related Characters: Richard Dawkins (speaker), Charles Darwin

Related Themes:

Related Symbols:

Page Number: 25

Explanation and Analysis

After asserting that people, like all living organisms, are essentially "survival machines" created by our genes to keep themselves alive, Richard Dawkins tells an origin story of life on Earth, to explain how genes came to exist, and then—many thousands of millions of years later—how we came to exist. Dawkins, drawing on Darwin, essentially condenses this history into a single process: evolution. For Dawkins, evolution is the story of replicating entities and the tools they create to survive. His story concludes with this quote, which sums up the entire history of life on Earth from the dawn of time to the existence of humans.

Dawkins starts at the beginning, when the universe was in a state of simplicity. When atoms floating around began to form very simple molecules, one happened to emerge with the capability of making copies of itself, or replicating itself: this first "replicator" is the ancient ancestor of DNA. Thousands of millions of years later, genes (DNA molecules) still do the same thing: they replicate themselves.

The only reason we exist at all is because the replication process is imperfect. When there are multiple slightly different (or miscopied) replicators all trying to make copies of themselves, the conditions for evolution arise: slightly different entities (replicators) are competing for finite resources (atoms). As competition for resources became more fierce, mutated (or miscopied) replicators with different capabilities that could to do things like build protective walls of protein around themselves were able to protect their atoms from being stolen, which is how cells—the earliest survival machines—evolved. The best replicators won the competition for atoms, until better replicators emerged that could build better survival machines, which enabled them to win. Human beings, and all living things, are just complex survival machines that do the exact same thing the first cells did: we enable replicators to stay intact, to make more copies of themselves, and therefore, to keep existing.

Chapter 3 Quotes

> It is as though, in every room of a gigantic building, there was a book-case containing the architect's plans for the entire building. [...] Incidentally, there is of course no 'architect.' The DNA instructions are assembled by natural selection.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Related Symbols:

Page Number: 28

Explanation and Analysis

Dawkins uses the metaphor of an architect's plans to explain how genes are distributed in living organisms: every single cell in a body (say, the human body) contains a complete copy of all the genes necessary to create a "survival machine." It's as if a huge building had a copy of its blueprints, or "architect's plans," divided into binders on a bookcase in every one of its room. In the metaphor, every room is a cell, each bookcase is cell nucleus, each binder is a chromosome, and each page is a gene.

Dawkins then addresses a core difference between his metaphor and genes: while the building in the metaphor is designed by an "architect," there is no architect in nature. This is a subtle dig at the idea of "God," which Dawkins vehemently disputes in his other writing, particularly *The God Delusion*. It also alludes to the fact that genes have no conscious intent. The genes that end up in the bookcase happen to be the ones that win out in natural selection.

> Genes have no foresight. They do not plan ahead. Genes just *are*, some more than others, and that's all there is to it.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 30

Explanation and Analysis

Shortly after asserting that there's no "architect" in nature—meaning there is no supernatural "God" or creator—Dawkins expands to explicitly state a point that he will stress many times in his argument. He often talks as though genes have selfish desires (to survive), and control or manipulate the survival machines they live in. However, this is not a literal description—selfishness is a metaphor for acting in a way that ensures your survival. Genes aren't conscious, nor do they make choices. They just "are."

Though he uses the metaphor of "selfish" genes to fuel the reader's imagination, Dawkins frequently encourages the reader to translate this metaphor back into blind evolutionary terms: the genes that exist just happen to be the ones that won out the competition for resources and therefore became more numerous. No more, no less. There is no intention behind their designs. In this sense, "selfish" really just means "good at surviving," or "happens to act in the interest of self-preservation."

> A gene is defined as any portion of chromosomal material that potentially lasts for enough generations to serve as a unit of natural selection.

Related Characters: Richard Dawkins (speaker), George C. Williams

Related Themes:

Page Number: 34

Explanation and Analysis

After having explained how genes are distributed through the body, Dawkins turns to the question of what a gene actually is. In the technical sense, a gene is a portion of DNA, or chromosomal material made of building blocks called A, T, G, and C. But Dawkins isn't concerned with specifying the content of a gene more specifically than that—he's more interested in bits of DNA that stay stuck together as they pass through different generations of organisms. Some of them might be bigger, and some of them might be smaller. So, one gene might be "ACC," and another might be "GTACTTAGT," while another might be an even longer string of genetic code. Smaller chunks are typically better at staying intact, because there are fewer components that might be miscopied (mutated), or reordered (inverted).

Dawkins (like Williams, from whom he borrows the definition), is only concerned with how a gene functions, not its specific constitution. That's why he says a gene is "any portion of chromosomal material" that passes through generations intact. In fact, if scientific research later discovered that genes have other components too, this wouldn't matter. As long as the entity replicates and lasts over a period of evolutionary time, it counts. It's is a functionalist definition of a gene: what matters is *how* it functions, and not what it's made of.

Each entity must exist in the form of lots of copies, and at least some of the copies must be potentially capable of surviving—in the form of copies—for a significant period of evolutionary time. Small genetic units have these properties: individuals, groups, and species do not.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 42

Explanation and Analysis

After Dawkins has specified that a gene is a replicator made of DNA, he articulates one of the central points of his argument: although many scientists try to decide between individuals and groups as the things that evolve, neither option is a candidate for a "unit" of evolution for Dawkins. Rather, Dawkins believes that genes themselves are what is evolving, and those genes just happen to outwardly manifest in individuals and species. He thinks evolution is only possible when differential entities are competing to survive (by becoming more numerous) in a world with finite resources. For groups or individuals to fit this description, they would have to replicate themselves by making identical copies or clones of themselves, but neither individuals nor groups do this. In this sense, Dawkins thinks group selectionists have overlooked something he believes is fundamental to the process of evolution itself: the necessity of a replicator.

The oarsmen are the genes. The rivals for each seat in the boat are alleles potentially capable of occupying the same slot along the length of a chromosome. Rowing fast corresponds to building a body which is successful at surviving. The wind is the environment. The pool of alternative candidates is the gene pool. As far as the survival of any one body is concerned, all its genes are in the same boat.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Related Symbols:

Page Number: 48

Explanation and Analysis

Dawkins introduces a new metaphor of "oarsmen," or rowers in a rowboat when he describes how genes get shuffled and reshuffled into groups with each generation. The oarsmen stand for genes, and each gene is competing to make the rowing team, or snag a seat on the boat. The metaphor is important at illuminating a central point in Dawkins's argument about gene cooperation, so he returns to it several times throughout the text.

A rowboat has eight seats, and needs eight rowers to make a rowing team. Each team member has a "selfish" motivation to win the race, but the team members need to work together to win. So, even though the team cooperates, the reason they cooperate is to satisfy their individual desires to win. Dawkins uses this metaphor to explain that genes do cooperate—in fact, he even thinks he could have called his book *The Cooperating Gene* and the argument would still be the same—but the only reason they cooperate is because cooperation increases their chance of winning a race, which satisfies their "selfish" motivations to be winners. Cooperation, therefore, only takes place when it is of individual benefit to each gene involved. Genes thus gang together to build organisms, or "survival machines," but only because each individual gene has a better chance of survival when operating in a group.

Chapter 4 Quotes

Nowadays the intricate mutual co-evolution of genes has proceeded to such an extent that the communal nature of an individual survival machine is virtually unrecognizable. Indeed, many biologists do not recognize it, and will disagree with me.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Related Symbols:

Page Number: 60

Explanation and Analysis

After his chapter on genes—what they are, how they're distributed throughout the body, and most importantly, how they function—Dawkins turns to organisms, or as he calls them, "survival machines." His first task is to dismantle the notion of a survival machine as an individual. It acts, operates, and feels like an individual, but actually, it functions that way because it contains a colony of genes acting in mutual cooperation for their individual survival. Each gene that cooperates has a better chance of survival when it combines with others to divide and conquer the task of building a survival machine, because the cooperation enables the construction of a more complex survival machine. It's so counterintuitive to think about an organism as a "communal" entity, that it's no surprise to Dawkins that many evolutionary theorists—such as Lorenz, Wynne-Edwards, and Wilson—got it wrong by thinking that evolution happens to organisms, rather than to genes.

Just as the Andromedans had to have a computer on earth to take day-to-day decisions for them, our genes have to build a brain.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Related Symbols:

Page Number: 70

Explanation and Analysis

Dawkins appeals to the science fiction book *A for Andromeda* by Fred Hoyle and John Eliot to explain why many organisms, like humans, have brains that make us feel like individuals with our own agency. In the science fiction story, a group of aliens called Andromedans want to control humans on Earth, but they live 200 light years away, meaning if they sent a message to people on earth, they'd be dead before a message came back. So, instead, they send out instructions for building a master computer that will do the dirty work for them, which humans decode and unwittingly build. The computer controls Earth the way a brain controls a body, but like the Andromedans's computer, the brain is programmed by genes. Since genes work by synthesizing protein, genes can't directly control their survival machines as quickly as a survival machine needs to act—say, to escape predators, or handle an unexpected event. So, genes build brains to do the dirty work of making short term decisions for them, but they're ultimately responsible.

Chapter 6 Quotes

[A] gene might be able to assist *replicas* of itself that are sitting in other bodies. If so, this would appear as individual altruism but it would be brought about by gene selfishness.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Page Number: 114

Explanation and Analysis

Many group selectionists rely on the observation that family members often sacrifice their individual well-being (or jeopardize their own chances of survival) for their relatives, to defend the idea of altruism in nature. When Dawkins tackles the issue of why family members are nice to each other, he immediately dismantles the group selectionists' notion with a very simple reminder: he refers to a gene as a single entity, but really what counts as an individual gene is the gene plus all its replicas in the universe. They are all copies or clones of each other, spread out into other survival machines. Since family members have a lot of genetic overlap with each other, it makes perfect sense that a gene who programs its survival machine to be nice to others who share a significant genetic overlap might do better in the gene pool than a gene who doesn't. Thus, although it appears as if there is altruism in family units, this perceived altruism only happens when it benefits replicas of genes sitting in other organisms' bodies.

Chapter 11 Quotes

But is there anything that must be true of all life, wherever it is found, and whatever the basis of its chemistry? [...] Obviously I do not know, but if I had to bet, I would put my money on one fundamental principle. This is the law that all life evolves by the differential survival of replicating entities. The gene, the DNA molecule, happens to be the replicating entity that prevails on our own planet.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 248

Explanation and Analysis

As Dawkins shifts his focus to discussing human culture, he makes an important claim about evolution that he revisits again later in his argument. Since he is offering a functionalist account of evolution, his argument revolves around situations in which the observed process matches the process of evolution. It doesn't actually matter what "things" are taking part in the process, it's the process that matters. He means that evolution requires there to be replicators (things of which copies are made) competing over finite resources. A gene is an example of a replicator, but anything that functions in the same way could also be a replicator, say, a replicating silicone-based molecule, or a digital virus, or—as he will shortly argue—ideas and trends in human culture.

Two important claims follow from Dawkins's assertion. First, his argument is applicable to more than just genes. It captures any process, anywhere in the universe, that involves replicators competing over finite resources. Second, he thinks ideas are also replicators in human culture, meaning there are two kinds of evolution going on for the case of humans.

❝❝ I think that a new kind of replicator has recently emerged on this very planet. It is starting us in the face. It is still in its infancy, still drifting clumsily about in its primeval soup, but already it is achieving evolutionary change at a rate that leaves the old gene panting far behind. The new soup is the soup of human culture. We need a name for the new replicator, a noun that conveys the idea of a unit of cultural transmission, or a unit of *imitation*. "Mimeme" comes from a suitable Greek root, but I want a monosyllable that sounds a bit like "gene." I hope my classicist friends will forgive me if I abbreviate mimeme to *meme*.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Related Symbols:

Page Number: 249

Explanation and Analysis

After Dawkins has claimed that multiple kinds of entities can fit the description of a replicator, he argues that we don't actually need to go looking for life on other planets to see if he is right. He believes there is a second type of replicator that has recently emerged on Earth, and this replicator is a "meme." Adapted from the Greek word for "imitation," a meme is a bit of human culture that gets copied and spread around in its "primeval soup." Primeval soup captures the pool in which a replicator floats around. For genes, the primeval soup was molecules floating around in space in the early stages of the universe. For a meme, the soup is "human culture."

Examples of memes include ideas, slogans, songs, literature, hairstyles, fashion trends, architecture—essentially, anything that's catchy, tends to get passed around, and crops up again and again in human culture. Just like genes, some memes are short-lived (say, a popular song, which might fade from memory within a generation), and others live much longer (say, the idea of God, which has been around for a very long time). Genes spread from body to body, but memes spread from brain (or mind) to brain. If a scientist hears about a new idea, he will talk about it with his colleagues, and teach his students about it. If they find the idea compelling, a copy of it will form in their brains, and when they talk to other people about it, more copies of the idea will be formed in other people's brains. Dawkins thinks if the concept of altruism came from anywhere, it came from a meme, and not from a gene. In other words, acting selflessly is something that is socialized and learned rather than an innate drive within human beings.

❝❝ We have the power to defy the selfish genes of our birth and, if necessary the selfish memes of our indoctrination. We can even discuss ways of deliberately cultivating and nurturing pure, disinterested altruism—something that has no place in nature, something that has never existed before in the whole history of the world. We are built as gene machines and cultured as meme machines, but we have the power to turn against our creators. We, alone on earth, can rebel against the tyranny of the selfish replicators.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Page Number: 260

Explanation and Analysis

A couple of times so far, Dawkins has asked if there's anything that makes humans different from other organisms on Earth. It would be quite depressing if it turned out that we're no different from a cell, or bit of seaweed in our purpose. Here, Dawkins provides his answer. In fact, there is something about humans that makes us unique. We shouldn't despair that we're just survival machines for genes, because we also have memes: our culture.

We have significantly more agency when it comes to memes. We can choose which ones stick with us, and which ones we'll spread to others. In this sense, humans have a power that no other organism on earth has. We have the power to go against the "selfish genes of our birth," and the "selfish memes of our indoctrination." Dawkins mentions indoctrination as another subtle dig to the idea of God, which—as an atheist—he thinks is no more than a very effective meme. The power to go against our genes, however, explains why we have a concept of altruism at all. While group selectionists think the concept comes from nature, Dawkins actually thinks it comes from a meme. He believes that nothing in nature acts purely in the interest of others if there is no benefit to its own genes, but this does not mean we should turn our backs on altruism. In fact, if anything, the onus is on us to work harder at cultivating the idea, since it won't happen any other way.

Chapter 12 Quotes

I agree with Axelrod and Hamilton that many wild animals and plants are engaged in ceaseless games of the Prisoner's Dilemma, played out in evolutionary time.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz , Robert (Bob) Trivers , William (Bill) D. Hamilton

Related Themes:

Page Number: 262

Explanation and Analysis

After discussing cultural evolution, Dawkins returns to the topic of biological evolution. He decides to tackle the issue of reciprocal altruism. He's already argued that relatives are kind to each other because they share a lot of genes, and acts of selflessness help their genes living in other bodies to survive. Now he addresses cases in which unrelated individuals are nice to each other. Animals often groom each other, for example, to pick parasites off each other's backs or heads, typically from places that an animal can't reach on their own body. It would seem that this altruistic. Group selectionists would argue that some individuals in a group are just naturally altruistic, but their altruism helps the group overall survive. Dawkins, of course, disagrees.

Dawkins, arguing in the same vein as scientists like Robert Trivers and William Hamilton, believes that reciprocal altruism in nature is explained by a strategy that results in the individual benefitting from being kind to others, because others will be more likely to help the individual back. Dawkins uses The Prisoner's Dilemma, is a hypothetical game that shows the expected penalties and payoffs when two people interact without knowing what the other person will do, in order to illustrate this idea. If the game is played only once, it actually makes more sense to be selfish (just in case the other person is too). But if the game is played multiple times in a row, each individual yields the highest rewards when they act nice at first, and then do whatever their opponent did on the previous round each subsequent time. And, more often than not, this is what tends to happen in nature. The Prisoner's Dilemma shows that animals who are nice to each other actually increase their personal chances of survival, and thus of their genes' survival. Even though such acts of kindness *seem* altruistic, they only exist when there is a greater individual payoff from being nice than from being nasty.

Chapter 13 Quotes

With only a little imagination we can see the gene as sitting at the center of a radiating web of extended phenotypic power. An object in the world is the centre of a converging web of influences from many genes sitting in many organisms. The long reach of the gene knows no obvious boundaries. The whole world is criss-crossed with causal arrows joining genes to phenotypic effects, far and near.

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 343

Explanation and Analysis

Toward the end of his argument, Dawkins summarizes some insights from another book of his, called *The Extended Phenotype*. In *The Extended Phenotype*, Dawkins tries to dismantle the idea of an individual as a good way to make sense of the things there are in the world. Although individuals are often thought of as discrete entities functioning in a shared environment, that's not a fully accurate picture of how Dawkins thinks the world really works. Genes do tend to concentrate their impact to a survival machine, but they also extend beyond it. A gene that programs a beaver to build a dam is more likely to survive in virtue of the dam that the beaver built which helped keep it alive. In this sense, the "phenotypic effect" (observable effect) of that gene is seen in the beaver as well as the dam. Similarly, when snail parasites excrete chemicals to make snails grow thicker shells, the gene in the parasite's body is having a phenotypic effect on the snail's body.

Dawkins thinks it would be much better to stop talking about individuals and environments, and start talking about genes and phenotypic effects. He uses the metaphor of a web radiating out from each gene to capture this: areas where lots of webs converge are what are often thought of as individuals, but this is an illusion.

> The only kind of entity that has to exist in order for life to arise, anywhere in the universe, is the immortal replicator.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Page Number: 344

Explanation and Analysis

Dawkins has just suggested that scientists think about genes and phenotypic effects, instead of individuals and environments. This suggestion is important for two reasons.

First, it's really the genes that matter—and their phenotypic effects extend beyond the individuals they're in. A phenotypic effect of a gene can easily manifest in another individual's body, or elsewhere in the environment. Dawkins thinks it's no wonder that scientists started talking about organisms when they thought about evolution, because that's what they see when they look around them. But he really thinks that when it comes down to it, the only thing that matters for biological evolution are genes and their phenotypic effects.

Second, genes matter because they are replicators. He implies that organisms are incidental to processes of evolution. They happen to exist, but they could just as easily not have existed. The only thing that's necessary is a replicator. Dawkins believes his account applies to all evolution, anywhere in the universe. Essentially, he thinks it has validity beyond genes alone.

Epilogue Quotes

> An organism has a frequency of one, and therefore cannot 'serve as a unit of natural selection.' Not in the same sense of *replicator* anyway.

Related Characters: Richard Dawkins (speaker), E. O. Wilson , V. C. Wynne-Edwards, Konrad Lorenz

Related Themes:

Page Number: 346

Explanation and Analysis

As Dawkins is ending his argument, he restates, for the final time, what he believes to be a central flaw in the group selectionist picture of evolution. Group selectionists like V.C. Wynne-Edwards and E.O. Wilson think that organisms (or groups of organisms) evolve on an individual or species level, respectively. But Dawkins believes that evolution is a process by which a replicator attempts to become more numerous, and therefore that the evolutionary unit is the replicator itself. In living things, this replicator tends to be the gene. The success of a gene can be measured by counting how many copies of that gene there are in the gene pool. But each organism is unique. It can't make a copy or clone of itself, so it always has a "frequency of one," meaning it fails to meet Dawkins criteria for a "unit of evolution."

> So powerful is the gene's eye view, the genome of a single individual is sufficient to make quantitatively detailed inferences about historical demography. What else might it be capable of?

Related Characters: Richard Dawkins (speaker)

Related Themes:

Page Number: 356

Explanation and Analysis

In closing his argument, Dawkins makes one final point. He prompts the reader to imagine the possibilities for human knowledge if people take the "gene's eye view" of evolution seriously. Dawkins has used the gene's eye view to show that no pure altruism exists in nature. But another thing that genes can do is tell us about our ancient past. Since genes are all clones of each other, they extend far back into history, even to the prehistoric era and beyond, to early replicators at the dawn of time.

This closing point serves two purposes. First, it serves as Dawkins's final snub to group selectionist scientists. He implies that the gene's eye view of evolution is a better theory because it can say more about the history of life on earth than group selectionists can ever hope to do. Second, Dawkins aims to spark the reader's imagination, just as he has throughout the book by using literary metaphors instead of technical jargon. Dawkins wants reader to be excited by the possibilities of taking genetic evolution seriously, so he ends by suggesting that ancient mysteries about life on Earth are encoded in our DNA.

SUMMARY AND ANALYSIS

The color-coded icons under each analysis entry make it easy to track where the themes occur most prominently throughout the work. Each icon corresponds to one of the themes explained in the Themes section of this LitChart.

PREFACE TO THE FIRST EDITION

Richard Dawkins suggests that the reader imagine his story is "science fiction." It is science, he says, and it's very strange, but it's no fiction. Dawkins admits that he is still astonished by his core claim that humans are "**survival machines**" programmed to preserve little molecules inside us called genes. He hopes the reader will be astonished too.

Dawkins encourages the reader to imagine his story is science fiction because he is aware that claiming humans are vehicles for our genes is quite radical, so he wants the reader to suspend their disbelief as they would when reading fiction.

Dawkins imagines his audience. First there is the general reader, or "dedicated layman," for whom he avoids using technical language in the book. In fact, he wonders why scientists don't do this more often. He hopes he has managed to distill technical ideas into everyday language, but he's not sure how well he succeeds. To Dawkins, biology is a mystery story, and he hopes at the very least that he's able to convey some of the excitement someone feels when reading a good mystery.

Dawkins draws another parallel with fiction when describing biology as "mystery story." He favors literary devices like metaphor and personification (which are more common in fiction) over technical language (which is more common in science). He thinks a more literary approach to his topic will help readers accept a somewhat counter-intuitive claim: that humans are essentially just by-products of genes trying to survive.

The second reader Dawkins imagines is the expert. Dawkins knows full well that experts will find his use of non-technical language frustrating, but he has to tell his story his own way. Perhaps, he suggests, this way of telling it will reveal something new about the topic that even an expert might not have seen yet. If not, he hopes it will at least be good reading for a train ride.

Dawkins aims to engage the reader's imagination, which is unusual in scientific discourse. He thinks that his somewhat radical claim that genes (and not species) evolve is easier to digest when communicated through personification and metaphor, so he encourages scientists to tolerate his nontraditional writing style.

The third reader is a student. Dawkins hopes the book will encourage students to become interested in zoology, because he thinks it's fascinating. For students who have already decided to study zoology, Dawkins suggests that his simple language might help them digest the more technical scientific papers he discusses.

Dawkins wants to shift the direction of research in zoology toward one that factors genes into the picture. He baits students with the promise of making technical material more digestible, but he also wants to get students on board with his view so that some of them might conduct research on genes in the future.

Dawkins characterizes himself as an ethologist, and he says this is a book about animal behavior. He believes most animal behavior makes sense if one thinks of it as the result of genetic traits that arise through evolution. Dawkins aligns himself with scientists who think that it's actually genes, and not species, that evolve. These "gene's eye view" scientists are George C. Williams, John Maynard Smith, William D. Hamilton, and Robert L. Trivers.

Dawkins names the scientists who function as "protagonists" in his story. These scientists think, like he does, that genes (rather than species) evolve. The phrase "gene's eye view" alludes once more to the literary device of personifying genes that Dawkins will use to get his argument across.

CHAPTER 1: WHY ARE PEOPLE?

According to Dawkins, intelligent life becomes "intelligent" when it starts to ask why it exists. There's been life on Earth for thousands of millions of years, yet he believes there wasn't have a credible explanation of why we exist until Charles Darwin argued that human beings evolved out of simple organisms. Many people still doubt Darwin's theory of evolution, but Dawkins is convinced that there's much more to be learned from it.

Dawkins believes that Darwin's theory of evolution can be used to explain a lot more than it has so far. Dawkins is hinting here that he sees more in Darwin's view than perhaps Darwin himself anticipated, including the biological evolution of genes, the cultural evolution of ideas, and even other forms of evolution.

Dawkins wants to understand selfishness and altruism from an evolutionary perspective, because these govern so much of human life, including loving, hating, stealing, fighting, greed, and generosity. The problem is, Dawkins thinks, that until now, these behaviors have been mischaracterized, because a lot of scientists, including Konrad Lorenz, think that evolution happens to groups, or species. But Dawkins thinks that humans (and every other living organism) are just "machines created by our genes."

Dawkins characterizes his central opponents: scientists (like Konrad Lorenz) who believe in the group selection view of evolution. They argue that evolution happens to species. A central point of contention between group selectionists and gene selectionists is the topic of altruism. Group selectionists believe that it does exist in nature, while gene selectionists think that it cannot.

If that's true, successful genes share one quality: selfishness. Sometimes it looks like animals are behaving selflessly, but underneath it all, that behavior really happens because it helps a gene survive. But this doesn't mean that it's okay to be selfish. In fact, it shows that people should try harder to be altruistic, since that tendency isn't biological.

Dawkins believes all behavior that looks altruistic is actually underpinned by genes acting to facilitate their own survival. Dawkins's thinks altruism needs to be cultivated especially because it doesn't exist in nature.

Of course, just because people are biologically programmed to be selfish doesn't mean we have to be. We might even think that culture has a lot more to do with our "nature" than biology. But even if genes have absolutely nothing to do with our behavior, we'd be the "exception" among all living things that breaks the "rule." Either way, we'd better find out what the "rule" is.

Dawkins drops a hint that he will eventually argue that altruism emerges from cultural, rather than biological, evolution. His claim that humans might be an "exception" also hints at a later conclusion that humans experience both biological and cultural evolution.

Dawkins clarifies something important. When he talks about "selfish" and "altruistic" behavior, he's not referring to how psychologically kind or cruel somebody feels. Rather, Dawkins thinks something (or someone) is altruistic when acting in a way that increases another's welfare at the expense of their own. In other words, Dawkins is only concerned with the effects of behavior on survival rates.

Dawkins uses "selfish" and "selfless" behaviors metaphorically to strictly stand for actions that increase or decrease one's own chances of survival, whether or not the behavior is intentional. This definition allows him to argue that evolution and self-preservation are directly linked.

Darwin would perhaps articulate altruism like this: somebody who acts selflessly makes themselves slightly more likely to die than the person who benefits from that altruism. If selfless animals are more likely to die, they'd be less likely to survive, reproduce, and pass on their altruistic traits, meaning that selfless behavior would die out in the long run. But it still exists, which seems paradoxical. Dawkins suggests that perhaps some behaviors seem altruistic on the surface, but they're really "selfishness in disguise."

Since altruistic individuals are more likely to sacrifice themselves, one would expect them all to be gone by now, and the world to be overrun with selfishness. Dawkins thinks altruism must be an illusion. His term "selfishness in disguise" implies that certain behaviors look like altruism, but serve the interests of genes under the surface.

For example, a female praying mantis will eat her mate if she gets the chance. So, it seems that the male praying mantis is acting selflessly in mating with her. Parents too, often sacrifice their own well-being for their children, which also seems altruistic. However, Dawkins argues that when individuals appear to be acting altruistic, they actually act that way because it increases the chance of their genes surviving.

Both the male praying mantis and the parent seem to sacrifice themselves. However, these behaviors aren't pure altruism because their offspring share their genes. The praying mantis's self-sacrifice and the parent's care thus pay off at the genetic level by enabling their genes to survive and be passed on.

Some scientists offer an alternative explanation for altruistic behavior, but Dawkins thinks they are wrong. V. C. Wynne-Edwards, for example thinks that some animals will sacrifice themselves to ensure their group, or species survives. Dawkins says this idea is appealing to human beings, because we tend to admire people who put others first, and we tend to value our own species over others. But this still doesn't explain why selflessness hasn't died out, considering that altruistic individuals in a group are less likely to survive and pass on those traits.

Dawkins wants to sway the reader away from Wynne-Edwards's group selection view by arguing that humans value altruism, so we try to find explanations for where it comes from, but nature is the wrong place to look. Selfless individuals who are prone to sacrifice themselves are unlikely to survive natural selection.

Another problem group selectionists face is deciding which "group" is the right one to analyze. Lions are in the group "lion," but they're also mammals. Does this mean they shouldn't kill antelopes who are also mammals (for the good of all mammals), and focus on birds? Dawkins thinks that sounds a bit ridiculous.

Dawkins aims to show that the "group" cannot be the unit of evolution because it's an unclear category. Lions and antelopes are different species, so they can be seen as different groups. Yet they are also mammals, and can be seen as part of the same group, which is contradictory. Therefore, the very notion of evolution happening on the group level is illogical.

Dawkins thinks that the "fundamental unit of selection" is self-interested, and this "unit" isn't the group, or species, or even the individual. It's the gene. Dawkins knows that this sounds a bit extreme, so to unpack the idea, he's going to start at the beginning with the origins of life itself.

Dawkins states two central claims of his argument. First, evolution must happen to "units" that are self-interested, meaning they act in ways that keep them alive (otherwise they wouldn't exist long enough to evolve). Second, this unit in nature is the gene. Dawkins empathizes with the reader in order to keep them following along until he can provide reasons for his views.

CHAPTER 2: THE REPLICATORS

At the start of the universe, there was just simplicity. Dawkins thinks Darwin's theory is appealing because it explains how the universe could start out as simple and become complex over time. Everything in the world is made of atoms that bumped into each other to form molecules. Some were unstable, and broke apart again, but stable molecules stayed connected. Dawkins thinks this was the earliest form of natural selection. Everything that exists today is made of stable molecules, from soap bubbles to the human body.

Dawkins starts with the early stages of the universe to argue that natural selection started happening before individual organisms (like plants, animals, or people) even existed. He wants to show that before "species" becomes a candidate for the thing that evolves, something else is going to come along first that works better as the unit of evolution.

Of course, nobody was around to see what happened back then. But it's likely that before life existed on Earth, there were chemical raw materials like carbon, water, and ammonia (because they exist on other planets too). In experiments, scientists who took these chemicals and exposed them to energy discovered that a weak **primeval soup** of more complex molecules formed. These were purines and pyramids: the building blocks of DNA.

Dawkins uses the common scientific metaphor of "primeval soup" to describe the universe in its early stages. "Primeval" means "very early in history" and "soup" is a metaphor for basic molecules floating around space like liquid in a soup: they are not quite solid objects (such as rocks and plants) yet.

At some point, a "remarkable" sort of molecule must have formed by accident. It was remarkable because it had the ability to make copies of itself. By "make copies," Dawkins means the molecule could attract atoms to attach in the same pattern as its original atoms. Dawkins call this a "replicator."

Dawkins provides the first example in this book of a replicator, which means something that has the capacity to make copies of itself, or replicate itself. The concept of a replicator is central to Dawkins's argument: he thinks evolution doesn't happen without replicators.

Of course, it's safe to assume that when things are copied, and those copies are copied, something might get copied a tiny bit wrong once in a while. The **primeval soup** would then have slightly different replicators competing for free atoms. This sets up the conditions for natural selection. Does this mean that the replicators were alive? Dawkins says that this is unclear, but what is certain is that the replicators are the "founding fathers," the ancestors of DNA.

Evolution can only happen when there are different entities competing for the same finite resources. Replicators that are good but not perfect at copying themselves create different entities. The number of atoms in primordial soup is finite, just like the amount of soup in a bowl. The bowl contains everything out of which solid entities can be made.

At some point, one of the slightly different replicators must have been copied in such a way that it had the capacity to "steal" atoms from others. That probably went on until another miscopy made a replicator with the capacity to build a "wall" of protein around itself, which would have protected its atoms. These were likely the first cells.

Dawkins personifies replicators to show that evolution demands the evolving "units" to be good at protecting themselves from destruction, which is implicitly self-interested (or, selfish).

As more occasional miscopies were made, it's likely that one replicator had the capacity to break down protein walls so that it could eat up the most molecules in the **primeval soup** and become abundant, until another miscopy created a replicator that could make a stronger, more robust protein wall. Dawkins suggests that this protecting shell can be called a "**survival machine**," since it keeps the replicators inside it intact, or "alive."

The name "survival machine" emphasizes the function of a cell: it keeps replicators intact. Once there are no more free-floating molecules in primeval soup, the universe changes from a metaphorically soupy stage to a world of more robust entities, described by their functions: replicators and survival machines.

This process would have continued for thousands of millions of years, just like that, with the **survival machines** getting more and more complex. That's where humans come into the picture: we are very complex survival machines that contain genes. Genes made us, and they "manipulate" us from inside. In effect, we are "lumbering robots" that replicators made to survive.

Dawkins argues that the function of a cell and a human is the same: both are made by replicators, and both are effective at keeping replicators intact. This is a functionalist account of evolution. It divides things up by what they do, rather than by what they're made of.

CHAPTER 3: IMMORTAL COILS

Dawkins thinks that humans are **survival machines**, and so are all other living entities on the planet as well, including "animals, plants, bacteria, and viruses." On the outside, it seems like these organisms are all very different. But on the inside, the base chemistry of every living thing is the same: they all contain replicators (genes, or DNA) that are more or less the same type of molecule. This molecule is shaped like a double helix (or coil), and is made up of four kinds of building blocks (called A, T, G, and C). The only thing that's different, between a man, another man, a snail, an octopus, an oak tree, and a fish is the order (or "sequence") of their genetic building blocks.

Dawkins wants to replace the traditional scientific view of dividing living beings into different species. He focuses on what all living beings have in common: they're all built by DNA (genes, or replicators). The only difference among species is the ordering of DNA building blocks. Species may look different, but they all function the same way: as "machines" built by replicators in order to survive.

Every cell of a body contains a copy of its DNA. DNA is a set of instructions (or "**architect's plans**") for how to build a body. Dawkins thinks it's similar to imagining a building with a bookcase in each room containing the architect's plans for that building. The bookcase is a "cell," and it contains lots of binders full of loose pages. The binders are "chromosomes." A human bookcase has 46 binders, and each page in each binder is a "gene." The only difference with the metaphor is that there is no actual "architect" in the case of DNA. The DNA instructions wound up that way because of natural selection.

Dawkins uses the analogy of an architect's plans to explain two facts about genes. First, architect's plans contain instructions for making buildings, just as DNA contains instructions for synthesizing protein into organisms. If one imagines that a building (body) contains a copy of its own blueprints organized into binders (chromosomes) on a bookcase (cell) in each of its rooms, one understands that every cell in a body contains the full DNA for building a new body. Second, genes aren't conscious. There's no intent, foresight, or "architect" behind the "plan" for building an organism.

Architect's plans have binders full of pages that come from people's mothers and fathers. One's mother's sixth page of her third binder might say "build blue eyes," and one's father's might say "build brown eyes." One of those pages will end up in one's own binder. Each sperm from one's father contains 23 "binders." When the sperm meets the egg (which also contains 23 binders), the pages from both sets of "binders" will be all mixed up and reorganized to create the set of binders that become the blueprints for oneself. They'll be so mixed up, in fact, that it's nearly impossible to figure out which exact page came from which parent. Genes are essentially shuffling around from body to body this way forever.

If an architect were to design a new building by taking half the blueprints (plans) from one building, and half from another building, and re-organizing their pages into a new set of binders, they would essentially be doing what nature does when the chromosomes of sperm and egg cells create embryos. A gene can pass from generation to generation intact, much like the way a page of instructions could be copied into a binder for a new building from an old one.

The actual picture is more complicated. Technically, a gene isn't an exact "page" but a bit of information that might be a sentence long, half a page long, or three pages long. It might even be split up across several pages out of order. Dawkins thinks it's unnecessary to worry about this though, as he's just using "gene" to mean any bit of chromosome that contains instructions that can be passed on intact (however long, short, or mixed-up the instructions are).

Although genes are more complex than Dawkins's metaphor allows, he's not concerned. Dawkins uses the word "gene" to capture the function of DNA (and not its exact structure). A gene is any portion of DNA that replicates itself (is copied, more or less intact, into a new body through reproduction).

Dawkins now explains how natural selection comes into the picture. Remember that genes are all copies of each other. Sometimes, there'll be a copying mistake, say, one letter on one page is copied incorrectly. This is called a "point mutation." Sometimes, the order will be wrong (it will be spelled backwards, for example). This is called an "inversion." Sometimes, by accident, the different order connects bits of genetic material that actually work better together. Externally, this means the body that's built will be slightly different. Internally, it means the new sequence will stick together more tightly and pass on in that new order instead.

Dawkins shows that the DNA replication process sets up the perfect conditions for natural selection to take place. All DNA has the capacity to replicate itself. If miscopies create slightly different replicators, they are technically competing for room on a chromosome in a sperm or egg cell. As noted, differential entities competing over finite resources trigger evolution by natural selection. Since this results in both external and internal (genetic) changes over time, Dawkins thinks it makes perfect sense to consider the gene the evolving entity.

Dawkins thinks that, because this is how natural selection works, the "thing" that is evolving must exist in lots of copies that can stay intact for long periods of evolutionary time. Genes have these characteristics. But individuals and species don't. This also means that, technically, the gene is immortal. It lives on in copies or clones of itself, potentially forever (if it's not miscopied). Genes are immortal coils of DNA. Individuals, then, are like temporary colonies or federations of genes that wind up living in the same body before they build a new one to move into.

Dawkins fleshes out his criteria for evolution to claim that replicators, by definition, stay the same over generations. They survive natural selection and therefore don't get replaced. Genes fit this description since they clone themselves, whereas individuals or groups don't. For example, a gene for blue eyes today is the identical clone of a thousand-year-old gene for blue eyes. But neither individuals nor species are identical to their ancestors, so it's a poor fit to consider them the evolving entities.

A "good" gene will live longer if it makes a better **survival machine** to live in. For example, a gene that instructs its survival machine to have longer legs (to escape fast predators more quickly) will live longer in an environment where there are fast predators. This means that at the genetic level, the gene is always "selfish," because genes that act in ways that preserve their existence win out in natural selection.

An organism is designed to allow the genes it contains to keep being passed on. Survival machines have one function: to keep genes in the gene pool. Dawkins reiterates that there is no altruism at the genetic level because genes won't win out in processes of natural selection if they act against the interests of their own survival.

Of course, genes also cooperate since they share **survival machines**. Dawkins uses another metaphor to explain this phenomenon: **oarsmen** in a rowboat. An oarsman cannot win a race by himself. He needs several colleagues to fill up the boat, each in a different position on the boat, and each with a slightly different skill set. The coach decides which people to put together by shuffling the potential oarsmen into teams and seeing which combination performs better together. The oarsmen are the genes, and they are competing for seats on the boat. Each **oarsman** is selfish: he wants to win the race. But he also needs to work well with his teammates to do so. So, an oarsman who's good at what he does and works well with other oarsmen will tend to be picked for the team.

Even though there is evidence of genetic cooperation, Dawkins still believes that all genetic behavior is fundamentally selfish. His metaphor shows that every oarsman (gene) selfishly wants to win the race. Winning a race stands for being successful in processes of natural selection. The oarsmen that do win races tend to row well together as a team. Similarly, genes that work well together build well-functioning survival machines, which makes them more likely to survive processes of natural selection.

Dawkins wonders why genes build **survival machines** that reproduce instead of just building bodies that last forever. He thinks that this is because evolution isn't perfect. Some "bad" genes slip through the cracks. There are likely late onset "lethal" genes that become activated in old age (say, a gene for "senile decay"). Because they don't cause the death of their survival machines before reproduction, they'll be more successful at slipping through undetected, which explains why they still exist, and why humans die.

The phenomenon of death appears to counteract Dawkins's claim that genes (and not species) survive. It would make much more evolutionary sense for genes to build survival machines that don't kill a whole lot of genes by dying. Dawkins needs to explain why death happens, so he argues that death is an imperfect outcome of natural selection. A gene that tells protein to start breaking down in old age will have already successfully passed on its clones through reproduction. It survives natural selection at the expense of other genes (and survival machines), whether ones likes it or not.

There's also another puzzle to think about. If genes are the things evolving, why do they build **survival machines** that reproduce and only pass on half their genes to the next generation? Dawkins thinks that's because colonies of genes don't care about staying together. There must be some evolutionary advantage to building a new body through reproduction, and likely the gene responsible isn't concerned with the survival of other genes. It's only concerned with its own survival. So, the gene cooperates with whichever other genes are necessary for it to keep replicating, regardless of which survival machine they come from.

Reproduction looks like it doesn't make sense from the genetic perspective either, because it appears inefficient as a form of gene transfer, which makes it an unlikely candidate for natural selection. Dawkins doesn't explain the evolutionary advantage of reproduction here (though he will later). Instead he emphasizes that clones of genes can easily coexist with compatible clones from other bodies. There is no evolutionary need for a level of genetic cooperation that keeps genes stuck together from survival machine to survival machine—that would imply a form of altruism among genes beyond what's needed for an individual gene to stay alive, which Dawkins doesn't believe in.

CHAPTER 4: THE GENE MACHINE

The topic shifts from replicators to **survival machines**, meaning organisms, including humans. Dawkins wonders why many organisms have brains. He thinks that at some point in history, a mutation or inversion must have given rise to a gene with the capacity to build neurons (brain cells). Neurons are able to coordinate muscle contractions at high speed. This means that that organisms with neurons are able to move about, escape from predators more effectively, and survive to reproduce. Dawkins explains memory in the same way. Memories enable movements to be learned and repeated, something that's also necessary for coordinated motion.

Dawkins knows that if he is going to convince his readers that human beings are really just protective shells built by genes to facilitate their survival, he needs to explain away all the things that make us feel we are too special to be mere survival machines. First, he tackles brains and memories by reframing both as capabilities that enable coordinated motion like running. This allows organisms to escape from fast-moving predators (or predators to catch fast-moving prey) so that they survive to reproduce and pass on their genes.

Another issue is the sense of agency that organisms have.—it doesn't feel like human beings are puppets controlled by little genes inside us. Dawkins thinks a good way to explain this is to think of genes as computer programmers. Programmers don't manipulate a chess-playing computer every time the computer needs to make a move. Rather, they program the computer with the rules of chess (or instructions for how to play chess), and the computer calculates what to do in the moment based on the instructions provided. Dawkins thinks this is how genes operate.

Dawkins explains that even though humans experience life as if we are free beings that make our own choices, our genes are still responsible for our experience. The computer programmer analogy shows that humans (computers) can only make choices within the parameters of our genetic "programming." So, even though it feels like we are acting freely, genes are ultimately in charge because they wrote the "rules."

It seems a bit strange that genes give so much control brains they build. Why don't they assert more direct control if their survival depends on it? Dawkins thinks they can't, because of "time lag problems." A good way to explain the phenomenon of "time lag problems" is the science fiction story "A for Andromeda" by Fred Hoyle and John Elliot. In the story, a civilization of **Andromedans** wants to control Earth, but they live 200 light years away. This means they can send out radio signals (which travel at the speed of light), but they won't live long enough to hear any responses from Earth. So, they send out coded instructions for building a computer (programmed to control humans on a day-to-day basis), which humans unknowingly decode and build.

Dawkins uses his Andromedans analogy to explain that while human beings do have powerful brains, that intelligence can't override the authority of our genes. Andromedans can't control humans by sending messages to them and interpreting human responses, because communication between Andromedans and humans takes so long. Similarly, a gene can't directly make a survival machine act quickly enough to function effectively in its natural environment (for running when seeing a predator). Like Andromedans, genes need a workaround, so they build brains.

Dawkins thinks genes "manipulate" organisms in the same way that **Andromedans** "manipulate" humans: indirectly. Genes work by controlling protein synthesis, but it's a very slow process. To get around this, genes build brains, which function to make short term decisions according to their genetic programming. The genes are "master programmers" and they are "programming for their lives."

The Andromedans and the instructions they send out represent genes. The resulting computer that's built represents an organism's brain: it does the dirty work of controlling humans that Andromedans can't do themselves. Similarly, genes can't synthesize protein quickly enough to enable survival machines to act in swiftly changing environments, so they create brains. But if this chain of command is followed all the way to the top, genes (like Andromedans) are indirectly in charge.

Because genes have to program **survival machines** and hope for the best after that point, the programming is a "gamble." One way that genes reduce the risk involved is to build organisms that can learn from their environments, to face unexpected circumstances as well as possible. This is where humans' sense of consciousness comes from, as we often run imaginary scenarios (or "simulations") in our heads before acting.

Even though individuals experience life as a unified conscious "self," including thoughts and imagination, these too are workarounds that help survival machines function when facing unexpected circumstances. Dawkins believes that feeling like an individual does not challenge the authority of the many genes that live inside is.

Finally, Dawkins addresses communication among organisms. Many **survival machines** communicate to enhance their chances of survival. For example, baby birds "cheep" when they are lost so their mother can find them. Some organisms even lie because it increases their survival chances. For example, a bird might make a sound to warn other birds that "there is a hawk" nearby, when there actually isn't one. The other birds will fly away, leaving all the food in that area for the chirping bird, which increases its chances of survival. Dawkins warns that whenever a system of communication evolves, "lies and deceit" (or "exploitation") should be expected to arise when the interests of different individuals diverge.

Dawkins also reframes communication as a tool that enable genes to survive. An organism that can communicate—either honestly or dishonestly—is able to leverage the behavior of other organisms in its quest for resources. Ultimately, Dawkins thinks that the things that make complex organisms seem unified as one thing—like coordinated motion, memory, choices, self-consciousness, learning, imagination, and communication—are really just tools that exist because they give the genes living inside an organism a better chance of surviving.

CHAPTER 5: AGGRESSION

Dawkins thinks that aggressive behavior has been largely misunderstood. He is going to describe these behaviors from the gene's eye view in order to clear up some of these misunderstandings. The first thing one should realize is that every individual is a "selfish machine," programmed by its genes to make the best use of its environment in order to survive. This "environment" includes other individuals. **Survival machines** of different species might compete for resources. They can be predators, prey, parasites, or hosts. Survival machines of the same species interact even more often. For example, they also compete for mates.

Many group selectionists argue that aggression in the animal world is much less hostile than it needs to be. A lot of animals hold back from fighting as hard as they can, so they think this implies evidence of altruism in nature. Dawkins disagrees, and he wants to convince the reader that he's right by describing a series of aggressive behaviors in nature from the gene's eye view, to show that genetic programming is never altruistic.

It might be logical to assume that a **survival machine** who competes for mates would do best by murdering its rivals (and maybe also eating them for food). Murder and cannibalism do happen in nature, but nowhere near as often as one might think. Lorenz, for example, talks a lot about the "restrained" way in which many animals fight. Lorenz says many animals fight to scare off others in their species, but not to kill them. On the surface, this looks like a form of altruism, but Dawkins disagrees.

Lorenz, a group selectionist, considers the fact that animals don't murder, fight, and eat each other as much as they could as evidence for altruism in nature. Dawkins will counteract this claim by showing that these behaviors are avoided when they keep genes alive, which is a selfish rather than altruistic cause.

Indiscriminately killing every rival that crosses an individual's path won't always be the best survival strategy. This comes down to a simple "cost-benefit analysis." Imagine that one face two rivals (B and C). If one meets B first and kills him, one will be spending energy to do that, and then one also has to deal with C. But if one lets B live, he might fight with C and leave one to use one's energy in better ways.

Dawkins needs a way to measure altruism and selfishness in nature. His example here shows that it's not enough to look on the surface of the action—the overall benefit or cost of that action to the actor in the course of their lifetime also needs to be considered.

Dawkins thinks that Maynard Smith has a good way of explaining behavior strategies in animals from an evolutionary perspective. Maynard Smith uses the term evolutionarily stable strategy (ESS) to describe behavior that best increases the chance of survival, relative to the way others in the environment behave.

An evolutionarily stable strategy or state is achieved when the same ratio of replicators persists in the gene pool from generation to generation. It's a way of measuring behavior that factors in the response from others in the environment, and calculates the overall chances of the gene for that behavior being passed on in the long run.

Imagine there are two kinds of fighting strategies in a society. "Hawk" is an aggressive strategy, because hawks fight hard, but they tend to win. "Dove" is a less aggressive strategy, because doves only threaten, but don't actually fight.

Dawkins uses the hawk and dove behavior strategies to explain that nice (dove-like, or less aggressive) behavior only exists when it keeps the genes causing that behavior in the gene pool in the long run.

In a society where all the creatures use the dove strategy, nobody gets hurt. But if one creature mutates and starts acting more aggressive (or hawk-like), it will win all the fights, get food and territory, and mate the most. So, the next generation would contain more aggressive individuals, who are more likely to fight and injure themselves. This means that individuals who act less aggressively (or act dove-like) would then end up less likely to become injured, and therefore survive to reproduce.

Evolutionary unstable strategies arise when a mutation causes a new behavior that takes over the gene pool for a while, but eventually dies out (or nearly dies out) when it becomes too numerous. It implies a bit of evolution almost happened, but failed.

Each generation goes back and forth in aggressiveness like a "pendulum" until a particular balance of more and less aggressive behaviors become "stable," meaning they stay relatively consistent from generation to generation. This is called an evolutionarily stable strategy. One can also think of an evolutionarily stable strategy as a situation in which the number of hawk-genes and dove-genes stays consistent from generation to generation. Put another way, this means the ratio of hawk-genes to dove-genes stays stable in the gene pool.

The proportion of act-calm genes (dove genes) and act-aggressive genes (hawk genes) swings back and forth—with one gene taking over each generation by winning the mating game—until a happy medium (or evolutionarily stable strategy) is reached, and the ratio stays consistent over time. A stable ratio enables a gene to guarantee its survival over many generations.

Many perplexing animal behaviors start to make sense when one realizes they are the result of evolutionarily stable strategies. These include behaviors like "gloved fist" aggression, meaning threatening but not always fighting, or the "poker face," meaning bluffing.

On the surface, it looks like some animals act less hostile (potentially altruistic), while others are aggressive (selfish). Really, however, their genes just settled on a balance (evolutionarily stable strategy) that won't cause those genes to be nearly wiped out every other generation. What looks like altruism in the short run is actually selfishness in the long run, as it facilitates gene survival in the large-scale picture of evolutionary time.

Maynard Smith says there are three factors affecting behaviors that will become evolutionarily stable strategies. The first is differences in size and strength. For example, large animals are more likely to benefit from being aggressive than small animals. The second factor is age differences. An older bird (who has already mated) has less to lose from fighting than a young one who has yet to mate. The third factor is chance: happening to be in the right place at the right time.

The actual genes that do *persist in a gene pool over time depends largely on environmental factors, but Dawkins thinks altruism is never responsible. Aggressive genes persist when the survival machine is large or strong, or when they program risky behavior to kick in only after reproduction has already occurred and clone-genes have already spread. Sometimes, a risk just pays off by chance.*

Many scientists assume that dominance hierarchies arise in groups to make the group overall less aggressive, which seems beneficial for the group overall, even if those lower in the hierarchy suffer. But Dawkins thinks that dominance hierarchies are just another example of an evolutionarily stable strategy.

Dawkins thinks group selectionists are wrong to think that dominance hierarchies exist because some animals are naturally altruistic and let other animals dominate them for the sake of peace in the group overall. He thinks a combination of calm and aggressive temperaments persist in a group because the ratio of calm to aggressive genes is stable in the gene pool, and therefore keeps those genes alive, meaning there is no altruism involved.

R. D. Alexander conducted an experiment showing that crickets act less aggressively if they remember losing fights in the past. Dawkins thinks this means that animals who tend to win fights act more aggressive over time, enabling them to assert dominance. Meanwhile, animals that tend to lose fights act less aggressively over time, keeping the aggressive animals in charge. That's how dominance hierarchies come about.

Dawkins wants to provide explanations for behavior that don't rely on altruism, to support his core argument that altruism does not exist in nature. He uses Alexander to show that less aggressive animals don't hold back to be nice, but play it safe and avoid fights they might lose.

Many scientists also assume that animals tend to avoid cannibalism because of some inherent altruism toward others in their species. Dawkins thinks that this is wrong. He thinks many behaviors that look altruistic exist because they happen to be evolutionarily stable strategies.

Dawkins also thinks cannibalism doesn't happen because of animals being kind to each other. He would rather say that the gene fails to persist in the gene pool in the long-term.

For example, lions eat antelopes, but they don't eat other lions. Dawkins thinks it's not an evolutionarily stable strategy for lions to be cannibals. If a lion eats all the other lions who are its rivals for mates, it will be able to mate more and pass on its cannibalistic trait more widely. Then more cannibalistic lions would be born, but they'd be more likely to be eaten by each other, causing the trait to eventually die out in lions.

The lion example shows that cannibalistic lions might win out over a single generation, but the gene for cannibalism would ultimately fail to maintain a stable (and therefore ongoing) presence in the gene pool over time. It's not altruism that stops animals from eating each other. The cannibal gene just doesn't survive evolutionary processes.

Similarly, an antelope that decides to fight back when attacked by a lion is more likely to be eaten (simply because the lion is stronger), so it fails to survive and reproduce. Dawkins thinks the general tendency for lions to chase antelopes and for antelopes to run away is evolutionarily stable. In the long run, this combination of behavior strategies keeps enough antelopes and lions alive for these respective traits to be passed on.

Similarly, genes for aggression in antelopes don't survive natural selection because those survival machines fail in an environment with strong predators. Antelopes aren't altruistic, the ones that run away are just better at staying alive and keeping those genes in the pool.

Dawkins believes that explaining behavior in terms of evolutionarily stable strategies is going to be one of the "most important advances to evolutionary theory since Darwin." Dawkins thinks this type of explanation is important because it shows how a group of selfish organisms can resemble "a single organized whole" that appears to be cooperating for the good of their species.

Dawkins believes that thinking in terms of evolutionarily stable strategies poses a profound challenge to group selectionists. They believe that some animals (who are naturally altruistic) sacrifice themselves and others (who are naturally selfish) don't, but overall the species as a whole evolves. Evolutionarily stable strategies show animals are never purely altruistic. Differences between selfish and altruistic individuals in a group are accounted for by the ratio of genes for those temperaments in the gene pool. The ratio only persists for selfish reasons: it keeps those genes in the gene pool for many generations.

The evolutionarily stable strategy concept is also useful for explaining why genes appear to "cooperate." Dawkins revisits the **oarsmen** metaphor to explain genetic cooperation. Imagine the coach is mixing up candidates at random to see which ones work best as a rowing team. If, by chance, one of those teams is made up of four left-handed rowers and four right-handed rowers, they'll tend to perform better. Dawkins thinks it might look like the coach picked them as a unit, but in actual fact, they came together by chance.

Dawkins believes that evolutionarily stable strategies explain competition among genes within a survival machine as well. Once again, Dawkins intends to show that there's no altruism going on here. Genes that work well together tend to stay in stable ratios over generations of reproduction (in the same way that oarsmen who happen to row well together tend to be put together on an ongoing basis).

In general, it's hard for a new **oarsman** to infiltrate a well performing team. For example, replacing one of the right-handed rowers with a left-handed one will throw the team off balance and undermine their overall performance. Similarly, it's hard for genes to infiltrate a **survival machine** that is already a fine-tuned mixture of genes that cooperate well. This is why most new mutated genes getting shuffled into the gene pool do not survive to reproduce. They throw off the balance that has prevailed from generation to generation, and most likely cause their survival machines to perform more poorly in their environments.

A new gene will destabilize the balance of genes in a gene pool until a new stable ratio is achieved. Dawkins shows that the oarsmen analogy explains this because new candidates for a team usually throw off the way the team is used to working and don't get picked to replace an existing team member if the team is already working well. The oarsmen stay intact as a team over time because the team wins, and not because of any altruism among team members who want to stick together for the sake of it.

Once in a while, a new gene will make a **survival machine** work better. There will be a transition period of instability, which tests how the enhanced survival machine functions in its environment relative to other organisms. If the environment overall finds a new balance, it becomes stable under these new terms, and a new evolutionarily stable state is reached. This means "a little bit of evolution has occurred."

Dawkins explains that evolution happens to genes, and not individuals or groups by describing a moment of evolution from the gene's eye view as the achievement of a new evolutionarily stable state. Crucially, a "little bit of evolution" only happens when a gene is able to persist *in the gene pool. It keeps replicating in multiple survival machines over multiple generations. When that happens, a different ratio of genes has become stable.*

So far, it has made sense to think of each organism as a single "selfish machine" but this model runs into problems for family members, because relatives are often unselfish toward each other. Dawkins thinks that selfless behavior within families actually makes perfect sense, because relatives share genes.

While group selectionists believe that kindness between family members proves that altruism exists and species are the things evolving, Dawkins believes that kindness in families only happens when it increases the total number of clone-genes in the pool, regardless of which survival machine they come from. Once again, this is a self-preserving (and not altruistic) behavior.

CHAPTER 6: GENESMANSHIP

Dawkins recalls that the "selfish gene" isn't just one standalone gene, it's also all of its replicas, distributed throughout the world. A selfish gene is trying to become more numerous in the gene pool. Dawkins says the key point of this chapter is that "a gene might be able to help *replicas* of itself that are sitting in other bodies." He thinks this explains why behavior among relatives (such as parents and children) appears altruistic, when it is in fact "brought about by gene selfishness."

While group selectionists believe that individuals are selfless toward family members because it helps the species survive, Dawkins believes that individuals are kind toward family members because relatives contain copies (replicas or clones) of the same genes. Once again, he argues there is no altruism in play here. He emphasizes this by saying that the "selfish gene" includes all the copies of that gene in other bodies.

Consider the gene for being albino. Theoretically, a gene for albinism could do well if it also programmed its **survival machines** to be altruistic toward other albino people. If the albino gene could make one of its survival machines sacrifice itself to save ten other survival machines with the albino gene in them, the albino gene would be doing well in the gene pool overall. But in reality, albino people don't go around sacrificing themselves to save other albinos. There is a simple explanation for this. Genes aren't conscious: they can't actively choose to make their survival machines act nicely toward others that contain their replicas.

Dawkins uses the example of albinism to remind the reader that genes aren't conscious, and can't choose which individuals to be nice to for the benefit of the genes living inside them. Technically, people share genes with strangers as well, but genes have to program their survival machines with rules that will have the best chance of keeping the genes alive and then wait out the life cycle of the survival machine, so choosing specific people to be nice to isn't in the cards.

In order for that to happen, there would need to be a gene that has two functions. First, the gene would need to contain instructions for building survival machines with very pale skin (or, say, green beards). Second, it would also need to contain instructions for building survival machines that are nice to other beings with very pale skin (or green beards, or any other detectable trait). But no such gene exists. The chances of those two functions coming about in one gene by a chance mutation are very low.

Theoretically, a gene could mutate that is able to build survival machines with a particular physical trait and the ability to recognize that trait in others, but this hasn't happened yet. Again, Dawkins is reminding the reader that genes can't choose the best ways to act the way a person can. A gene will survive if it happens to program a survival machine with behavioral traits that keep it and its replicas intact.

Dawkins wonders if some genes can detect copies of themselves in other **survival machines**, as it's clear that this ability would very well in the gene pool. He thinks the answer is yes. Close relatives (or "kin") have a high chance of sharing genes. This means a gene that programs its survival machines to be nice to their kin is more likely to keep replicas of itself alive.

Dawkins thinks that family members appear altruistic toward each other because they must contain a gene that programs them to recognize "kin." This gene would inadvertently help copies of its genes in those bodies, and thereby remain populous in the gene pool. If he is correct it means this behavior isn't altruistic. Rather, it exists because it's in the interest of the gene's survival.

Dawkins wants a more precise way of seeing if the altruism between family members happens in proportion to their shared genes, so he uses Hamilton's research. Hamilton worked out a system for calculating the odds of two individuals sharing genes. Hamilton figured this out by looking at how many shared ancestors two people have. If one does the math, one's first cousin is as genetically related to oneself as one's great-grandchild. A third cousin, on the other hand, is about as genetically close to oneself as any random person.

Dawkins uses Hamilton's research to prove his point. If individuals are nice to others in proportion to their genetic relatedness, then this shows that kindness only happens when it facilitates the survival of replica genes in other survival machines, and not because of any inherent altruism.

A gene for altruism toward distant cousins (by sacrificing oneself to save them) would be less successful in the gene pool than a gene for being altruistic to save one's siblings. Dawkins calculates that a gene for altruism will survive in the gene pool over time if the altruistic person saves two siblings at their own expense.

Genes can only program survival machines with rules for behavior and wait out the consequences. It makes sense that genes for being nicest to immediate relatives would do better in the gene pool, since siblings and parents have the closest genetic overlap with an individual.

A parent taking care of his or her child preserves the same number of genes as when it takes care of his or her orphaned sibling. Both the child and the sibling have 50 percent of the parent's genes. Dawkins thinks that "genetically speaking," there's nothing special about the parent/child relationship when compared to the brother/sister relationship. They are just two examples of gene preservation in **survival machines** that share 50 percent of their genes. It doesn't matter that genes aren't transferred from sibling to sibling the way they are from parent to child, since siblings share replicas of the same genes from their parents.

Dawkins emphasizes that sibling altruism and altruism toward children carry the same genetic benefits. This is important to remember, because from the gene's eye view, it doesn't matter which survival machine contains replicas of a gene—both the sibling and the child are equally valuable. This claim departs from the group selectionist view that parent relationships are closer than sibling relationships.

Many scientists use the term "kin selection" to talk about altruism between people who are related. Wilson, for example, thinks kin selection is a special kind of group selection. Dawkins disagrees. Hamilton's research shows that it doesn't matter so much exactly how two people are related. What matters is how many genes they are likely to share. Hamilton doesn't have to decide whether or not second cousins count as family to determine their likelihood of being nice to each other. He only has to think about degrees of genetic relatedness and explain altruism in those terms.

Dawkins thinks the group selectionist approach (of adding another kind of group selection into the mix, but within families) is problematic because it's not clear where to draw the line between family and non-family. He finds Hamilton's approach of simply calculating the proportion of shared genes (regardless of the specific relationship between two individuals) much simpler and more efficient. In scientific research, simpler explanations are often considered better, which implies that gene evolution is a more plausible explanation for behavior than group selection.

Dawkins thinks that of course in real life, organisms don't go about calculating the percentage of their genetic relatedness to other animals and then making decisions about who to be nice to on that basis. Even if they did, the calculation would be a little messier. They'd have to factor in relative age, life expectancy, environmental considerations and a host of other things. For example, grandparents and grandchildren share 25 percent of their genes. But grandchildren are likely to live longer than grandparents, so it makes sense for grandparents to take risks for their grandchildren, but not the other way around.

Dawkins believes that altruistic interactions between people happen because they facilitate gene survival across the whole gene pool, and not because of some inherent altruism. Sometimes this entails more complex calculations, such as factoring in life expectancy of the survival machines in question. Individuals don't consciously make calculations like this, so he needs to explain how these tendencies come about from the gene's eye view.

In order for altruism to evolve, the genetic payoff has to be higher than the genetic risk of the altruistic act. Although organisms don't go about calculating these risks and payoffs, behaviors that line up with genetic payoffs will tend to survive the course of evolution. For example, if I see some mushrooms on the ground, the genetic payoff of sharing them with my siblings (but not strangers) might be higher than if I ate them all myself. Of course, genes can't make decisions for their **survival machines** on a day to day basis. They program them with certain hereditary traits—or, "rules for action"—and wait out the ride as the brain interprets those rules each time it acts.

From the genetic perspective, a gene is more likely win out in natural selection if it happens to program a survival machine with behavioral traits that make its clone genes across the gene pool more numerous. So, programming a survival machine to share food with close relatives (who also contain copies of the gene in their bodies) might do more for the gene than programming its survival machine to hoard all the food it finds. Again, this is a self-interested motivation rather than an altruistic one.

Dawkins wonders what kinds of altruistic "rules" or behavior traits could be effectively pre-programmed into a survival machine. Behavior traits that will be successful over time vary from species to species. In a population with highly mobile organisms, a strategy like "be nice to people that look like you" might work, since it's more likely for siblings and parents to look alike than strangers. In birds, however, a strategy like "be nice to the others living in your nest" might be a good strategy, since it's likely the birds sharing a nest are genetically related.

Dawkins wants to explain that any kind of perceived altruism comes down to genetic programming that helps a gene (and its copies in other bodies) survive. Even though there are all sorts of survival machines in many different environments, he thinks the general principle holds that altruism is never responsible, only genes that happen to have the best programming instructions for the environment a survival machine encounters.

Chicks that find food, for example, often let out a low twitter that attracts other chicks. On the surface, this seems like altruistic behavior, but Dawkins disagrees. He says that chicks tend to move around by following their mothers, so chicks near each other will likely be siblings. The behavior, "make a low twitter when there's food" thus benefits the replicated genes living in a chick's siblings.

Dawkins uses the example of chicks to explain that underneath every behavior lies a gene with successful programming instructions, rather than a gene for altruism. Chicks tweet when they find food because they tend to move around with close kin, so tweeting isn't blind kindness. It benefits the same genes in their siblings, which keeps that trait in the gene pool.

However, there are still some behaviors that seem really problematic to explain in terms of their genetic payoff, such as adoption. Even worse, in the animal world, some bereaved mothers steal others' babies. Genetically speaking, this is doubly bad. The bereaved mother spends her energy on child rearing (at a detriment to the genes inside her own body), and also frees up the biological mother to spend energy further perpetuating her own genes. Dawkins thinks more research is needed on these cases. He speculates that perhaps stealing babies helps mothers learn child-rearing skills for when they mate again.

Dawkins worries that the gene's eye view picture of evolution doesn't have a good explanation for some behaviors, such as adoption, which has little genetic payoff for the adoptive parents. Group selectionists, on the other hand, easily make sense of adoption. For them, it's a case of altruism for the sake of the group. Nonetheless, Dawkins is still convinced that more research will yield an explanation that shows these are not examples of altruism.

On the other hand, genetic payoff explains why certain exploitative behaviors between species happen. Cuckoos exploit the behavioral trait of "be nice to birds in your own nest" by laying their eggs in songbird nests. Baby cuckoos stay alive at the expense of the unwitting songbird's energy, and mother cuckoos can preserve their own energy for other things. "Cheating" behavior stays in the gene pool because of its genetic payoff to cuckoos.

There are other behaviors, however, that the gene's eye view of evolution explains very easily, which implies it's still plausible. Examples include cheating and exploitative behaviors (such as stealing labor from other species by laying eggs in their nests). If such behavior benefits the cheater's genes, it will stay in the gene pool.

It turns out that songbirds evolved to recognize markings on eggs of their own species. Since that strategy had a genetic payoff to songbirds, it persisted. But then cuckoos evolved to make their eggs look more like songbird eggs. This strategy had a genetic payoff for them, and remained in the gene pool. Dawkins thinks that mimicking songbird eggs is an evolutionarily stable strategy for cuckoos.

Dawkins explains that the balance between exploiting cuckoos and exploited songbirds persists because stability has been achieved in the gene pool, despite various moments of evolution. He thinks this example shows that exploitative behaviors (as well as seemingly altruistic behaviors) can be explained in terms of the payoff at the genetic level, which makes his view more likely to be true.

Dawkins returns to the issue of parent/child versus sibling relationships. He thinks that natural selection will favor a degree of altruism that is proportional to the "best estimate of relatedness" between two individuals. It's important, however, to remember that animals don't go around calculating their relatedness to each other, they just have pre-programmed traits that either work over time or don't.

Dawkins wants to address the parent/child relationship more closely, because it seems that more altruism exists in this case over the case of siblings, yet siblings are as genetically related as parents and children are, so technically there should be no difference. He needs an explanation for this difference to protect his view from criticism.

The parental altruism gene is stronger in the gene pool than the sibling altruism gene because a mother is more likely to be correct in assuming a child that she cares for is her own. Siblings could unknowingly be half-siblings (sharing only a quarter of their genes) or adopted siblings (sharing no genes).

Dawkins believes the gene's eye view of evolution successfully explains the discrepancy between sibling and parental altruism. Parental altruism is simply stronger as a behavior because the genetic programming happens to be more successful.

Altruism toward children is also more common than altruism toward parents. The relationship is "asymmetric" because an altruistic child (who spends energy on keeping its parents alive at its own expense) is less likely to survive and reproduce than a selfish child. But, an altruistic parent (who spends energy keeping its child alive) is more likely to keep its altruistic genes in the gene pool than a selfish parent who lets their child die from neglect before it reproduces.

Dawkins also emphasizes that there is a genetic explanation for why altruism toward children is more common than altruism toward parents. Caring for children keeps more genes alive in other survival machines alive than any other form of care toward family members. Dawkins believes that even in families, altruistic behavior only arises when there is genetic payoff to the genes that family members share.

CHAPTER 7: FAMILY PLANNING

Many people consider parental altruism to be a separate from kin altruism in general. They often consider parental care to be an extended part of reproduction. Dawkins disagrees. He would rather think of things in terms of strategies for "bearing" new children, and "caring" for existing children.

Dawkins emphasizes again that he can explain all altruistic behaviors in terms of genetic payoff, and he doesn't need different explanations for parental altruism, kin altruism, and group altruism. He thinks his view is stronger than group selection theorists who need multiple types of explanations to make their picture of evolution and belief in altruism coherent.

Decisions in general entail choosing how to use one's energy. "Caring" decisions involve choosing how often to feed one's child, based on its "degree of relatedness" to oneself and its overall chances of survival. "Bearing" decisions involve choices like using one's energy to mate. Sometimes, caring and bearing decisions compete with each other, for example, when one wonders if one should care for an existing child or bring another into the world.

"Bearing" and "caring" are characterized in terms of energy spent making another individual more likely to survive, reproduce, and pass on their genes. Dawkins believes that family planning strategies (like other behaviors in the natural world) exist because genes for those behavior traits win out in natural selection.

Dawkins thinks that, depending on the species, different combinations of caring and bearing will be evolutionarily stable strategies. The only strategy that will not be stable is a "caring only" strategy. If every animal in a species spent all its energy caring for existing animals instead of mating, then no new animals would be born, and the species would die out.

Once again, Dawkins believes that there's no altruism involved in family planning. He thinks that when animals in a species display common strategies for child bearing over multiple generations, it means that a fixed ratio of bearing to caring has become stable.

Mammals tend to invest in "caring" strategies. Decisions to bear a new child are often followed by decisions to care for that child, and parents tend to choose feeding their children over other relatives. From a genetic perspective, both one's brother and one's child both share half of one's genes, so it shouldn't make a difference which one a person feeds. However, since "caring only" strategies don't fare well in the gene pool, and one didn't give birth to one's brother, one is still more likely to feed one's child.

Dawkins uses bearing/caring language to explain that favoring children to siblings makes sense from a genetic perspective in these terms as well. Individuals who are programmed by their genes to care for others (say, siblings), but not to have their own children don't mate as much (if at all) so there are fewer of those genes being replicated in the gene pool.

Wynne-Edwards thinks that animals deliberately reduce their birth rates as a form of altruism to the group at large. Dawkins disagrees. He thinks it's an attractive hypothesis, since it's good advice for humans, otherwise we'll run out room on the planet. Nonetheless, he thinks actually, predators, disease, and starvation keep things in check (with the exception of humans, who rarely get hunted any more). In fact, Dawkins agrees with Wynne-Edwards that animals regulate their birth rates—he just disagrees about *why* they do. Wynne-Edwards thinks animals do it because they are altruistic toward the group, but Dawkins thinks there are underlying selfish reasons.

Group selectionists like Wynne-Edwards argue that altruism exists in nature because animals regulate their birth rates to avoid overpopulation, which benefits the group (the evolving entity) as a whole. Dawkins, on the other hand, thinks that often, having few children keeps more of an animal's genes in the gene pool than having many children. Once again, the gene's presence in the gene pool (and not the group's presence in the world) is being maximized. Since the behavior keeps more genes alive, there's no self-sacrifice involved.

Wynne-Edwards gives three reasons to support the idea that population control is altruistic in animals. First, animals often fight over territory. Losers usually don't breed, presumably so that stronger "winners" can breed and benefit the group as a whole. Next, animals also often have dominance hierarchies. Those low in the social order similarly avoid breeding. Finally, animals have "epideictic displays," meaning they swarm or flock as a group. Wynne-Edwards thinks epideictic displays enable group members to estimate their population size and avoid breeding when the swarm is overcrowded, all for the good of the group as a whole.

Wynne-Edwards gives several explanations for animal behavior that characterize choices not to mate as examples of altruism. Group selectionists like Wynne-Edwards think that animals who choose not to mate (or limit their amount of mating) are naturally or biologically altruistic, and that this altruism persists because it keeps the group alive, and therefore evolving.

In contrast, Dawkins wants to show that when animals don't breed as much as they could, it's because of their "selfish" genes. In order to do so, Dawkins references David Lack, who researches "clutch" (or flock) sizes in wild birds. Lack argues that birds have an "optimal clutch size." Although each bird could lay as many eggs as possible, many don't. This is because more energy spent "bearing" means less energy available for "caring." So, there must be a ratio of bearing to caring that maximizes number of surviving children overall. This is the optimal clutch size. Wynne-Edwards thinks it's the clutch size of the group overall that's optimized. But Lack thinks each bird is choosing the clutch size that maximizes her own offspring.

Dawkins uses Lack's theory of clutch sizes in birds to offer different explanations for each of the examples that Wynne-Edwards raises. Dawkins believes that in each case, decisions about how many children to have exist in nature purely because those choices maximize an individual's genes in the gene pool, and never because of altruism toward the species at large. Wynne-Edwards takes "optimal clutch size" to be the number of children a bird will have that allows the species to stay alive. Dawkins, however, takes "optimal clutch size" as the ideal number of children a bird should have if they want to keep as many of their genes in the gene pool as possible.

For example, a bird that lays four eggs has to divide up the available food between four chicks, but her neighbor, who only has three chicks, can give each chick more food. It could easily turn out that the neighbor keeps all her three chicks alive, but the bird with four chicks is only able to keep her two strongest chicks alive. Dawkins believes that even though it looks like birds are being altruistic for the good of the group when they lay fewer eggs than they can, they are really trying to maximize the number of surviving offspring they have, which is a selfish motivation.

Birds divide up their energy by bearing and caring for children. A bird that gives some energy to bearing, and some energy to caring will often keep more birds alive than a bird who uses all their energy to bear children, but doesn't care for them at all. Dawkins thinks birds only have fewer children than they can (or smaller clutch sizes) when it's the best strategy for keeping their genes in the gene pool in the long-term picture. This, once again, is a selfish and not altruistic motivation.

Put another way, natural selection adjusts the initial clutch size according to available resources in the environment. Individuals who are prone to having too many children keep fewer children alive, meaning they have fewer grandchildren, and fewer genes in the gene pool overall. The individuals inclined toward having just enough children (to maximize survival chances given available resources) will be favored by natural selection.

Dawkins implicitly reminds the reader that genes aren't conscious, and can't choose how to make birds act. Rather, the genes that happen to program birds to divide up their energy between bearing children and caring for them will win out in natural selection over genes that only program birds to bear children.

Dawkins thinks that Lack's theory can explain all the examples Wynne-Edwards discusses. For example, it seems like birds who lose fights and fail to secure territory are being altruistic toward the group by not breeding. However, their best strategy might be to wait until a bird with territory dies and swoop in on the vacant territory, because they know they're bad at winning territory by fighting for it. Similarly, animals who are low in the pecking order might be waiting for their optimal chance to breed (rather than holding back for the good of the group). Dawkins thinks what looks like altruism can once again be explained by selfish motivations.

Wynne-Edwards thinks that birds who lose fights or aren't dominant in a group let the stronger ones breed because that's better for the group overall. If that's what some birds do, then it means that the group overall is the thing evolving, and the altruism helps that happen. Dawkins disagrees, and thinks birds who lose fights don't hold back to be nice. They just hold back until they have a better chance of getting territory to breed. In other words, they save their energy because they want to have the best shot at keep their genes alive in the future, and not for the sake of the group.

Dawkins agrees with Wynne-Edwards that "epideictic displays" (like swarming) might be a way of estimating population size. But Dawkins's story deviates from there. Imagine that starlings can estimate the population of starlings in an area, and lay fewer eggs in seasons when competition for food will be greater. From a selfish perspective, it would then also make sense to trick other starlings into thinking the population is denser than it actually is (so that the others lay fewer eggs, leaving more resources available). Maybe epideictic displays (like flying around in a swarm, or chirping loudly in unison at sunset) are ways to trick others into thinking the group is denser than it actually is.

Wynne-Edwards thinks that groups of birds or flies swarm together and make lots of noises (epideictic displays) to count how many they are in the population and stop breeding if they are too many. Once again, this would be altruistic behavior that keeps the group alive and evolving. Dawkins disagrees, because he thinks such displays are selfishly motivated. They are ways to trick others in the group into thinking smaller clutch sizes will maximize their genes being passed on.

CHAPTER 8: BATTLE OF THE GENERATIONS

Dawkins wonders if it is a good strategy for a mother to have a favorite child that she invests in more than others. He borrows a way to measure parental investment (PI) from Trivers, who argues that parental investment is "any investment that increases the offspring's chances of survival (and hence reproductive success) at the cost of the parent's ability to invest in another offspring." Resources a child uses up (such as a pint of milk) are measured in terms of the decrease in life expectancy to his or her (existing or future) siblings. Dawkins supposes that an adult has a fixed amount of parental investment to distribute in her lifetime. This includes food gathered, risks taken, and energy spent caring for her children. What would be a wise investment policy for her to follow?

Dawkins wants to see if the way parents divide up their energy among their children matches behaviors that enable more genes to exist in the gene pool. He thinks it will, and this will help strengthen his claim that genes (and not species) evolve, so he appeals to Trivers's concept of "parental investment." Parental investment measures resources distributed among children in terms of impact on survival rates. The more parental investment an individual receives, the more likely they are to stay alive, reproduce, and pass their genes.

The reader already knows from Lack that she shouldn't have too many children and spread her parental investment so thin that her young don't survive to reproduce. But should she invest in some children more than others? Dawkins says no. Genetically speaking, each child has half of her genes, so the optimal strategy (to maximize the number of her genes in the gene pool) is to invest equally in each.

From a genetic perspective, it seems like the smartest thing for a parent to do is divide up their "parental investment" equally among all their children, since each child is equally genetically related to a parent. Sometimes parents do *have favorites though, so Dawkins needs to show that favoritism only happens when it results in more genes being passed on.*

However, there are other considerations to factor in. A runt has a lower life expectancy than his siblings. It may be wise for the mother to reject the runt and distribute his or her parental investment among her other children. It may even be smart to kill the runt and devour him or her, or to feed the runt to his or her siblings.

Favoritism toward stronger children makes selfish genetic sense: strong children are more likely to survive, be attractive mates, successfully reproduce, and pass on their genes.

Similarly, if a mother can only save one of her two children, it's wise for her to save the older one, since she'll need to expend additional parental investment to get the younger one to the older one's age. On the other hand, if she's deciding who to give food to, it might be wise to feed the younger one who is weaker and less able to find his own food. It also makes sense that mothers wean their children when they are strong enough to seek their own food. From the mother's perspective, it's wiser to save her remaining parental investment for her next child, rather than spend it on a child who is now capable of fending for himself.

Age favoritism can go both ways. Weaning children indicates a shift from caring for an existing child to bearing a new child. Dawkins thinks the strategy (about favoritism, or when to wean) that will win out in the long run is whichever strategy keeps the most of a parent's genes alive. In each case, the root cause is genes that are better at becoming more numerous in the gene pool, rather than actions that benefit the group as a whole.

Dawkins wonders why females go through menopause. He thinks the abrupt way menopause comes on seems to imply it's an adaptation, and concludes that menopause probably happens because women get less efficient at bearing children as they age. If a woman has a child and a grandchild born on the same day, her grandchild has a greater chance of survival than her child. Grandmotherly altruism probably exists because women who were altruistic toward their grandchildren increased the chances of keeping their genes in the gene pool, and passed on the tendency to be caring toward grandchildren. Dawkins believes that focusing on the genetic payoff to one's genes in one's relatives' bodies explains all kinds of kin altruism.

Grandmotherly altruism genes and menopause genes likely became numerous in the gene pool because grandmothers who care for their grandchildren help to keep some of their own genes in their grandchildren's bodies alive. At older ages, grandmotherly altruism keeps more shared genes alive than bearing new children. Dawkins believes that all behaviors between family members that look like altruism on the surface only exist when there is a "selfish" payoff to the individual's genes, which keeps those behavioral traits in the gene pool.

Dawkins then asks what the optimal survival strategy is for a child competing with its siblings for resources. Genetically speaking, one's sibling (like one's parents) has half of one's genes in its body. But on the other hand, one has all of one's genes in one's body, so it may be wise to try to "grab" more than one's fair share of parental investment. Dawkins thinks this is why piglets often race to reach their nursing mother. On the other hand, it might benefit one's genes if one let one's younger (and weaker) sibling have more than their fair share of parental investment. An "elder brother may have exactly the same ground for altruism as a parent." There's a genetic payoff to caring for replicas of one's genes in one's siblings' bodies.

Dawkins thinks the gene's eye view of evolution explains both selfish and altruistic behaviors among siblings. In either case, the prevailing behavior is the one that keeps the most genes alive, whether these genes are in an individual's body, or in their sibling's. Genes for different behavior traits compete in the gene pool, and the winning genes program their survival machines with certain behavior tendencies. Observed tendencies may appear either altruistic or selfish, but in both cases, the "selfish" gene has won.

From a child's perspective, there's a point in time when it benefits his or her own genes to wean him- or herself so that his mother can invest in another child which also has some of the same genes. This point in time is usually much later than the optimal time for the mother to wean him or her (which is whenever he or she has had his or her fair share of her lifetime parental investment). This is likely is why children often resist weaning, but eventually accept it.

Dawkins also looks at cases in which family members have a dispute, to show that these behaviors can also be explained by selfish genes. He explains that weaning disputes happen because the child's selfish genes (which are better off when they can delay spending energy on seeking food) and the mother's selfish genes (which are better off when investing energy in a new child) are competing for resources.

Dawkins believes that many child behaviors exist because of the genetic payoff across siblings. For example, pretending to be the hungriest sibling (and chirping the loudest) likely survived in the gene pool as a behavioral trait in young birds because it works. On the other hand, some runts give up and stop competing for food. This is because one of the runt's siblings likely also has the gene for "give up when you're too weak" and the runt giving up keeps that gene in the gene pool by way of the runt's sibling, who becomes stronger by taking the runt's share of parental investment.

Dawkins repeats the strategy of showing that selfish behaviors (such as a bird chirping loudly to pretend they're hungrier than they actually are) and altruistic behaviors (such as giving up competing for food) both take place when the gene for that behavior is successful at replicating, regardless of which sibling it's in. He wants to show this explanation applies to as many behaviors as he can, so he keeps going.

In general, it's a wise strategy for children to lie and cheat to get as much parental investment as possible. A. Zahavi even speculates that some birds chirp to attract predators to their nest, forcing their mothers to feed them and keep them quiet. Dawkins is skeptical about this strategy surviving in the gene pool, because he thinks it's too risky.

Dawkins mentions other theorists (like Zahavi) who also think that many puzzling animal behaviors make sense when addressed in terms of genetic competition. By naming Zahavi, Dawkins shows he has allies who endorse his general claim that selfish genes write the story of nature, even if they quibble over details about specific behavior traits.

Dawkins admits, however, that there are some diabolical strategies that pay off in the long run. Cuckoos (who hatch in "foster" nests) tend to hatch earlier than their foster siblings. It's smart for cuckoos to throw the other eggs out of the nest and hog the parental investment, especially because the cuckoo is not genetically related to the other eggs in the nest. Similarly, there can be a substantive genetic payoff for a swallow who throws out one of the eggs in its nest. Since the swallow is genetically related to its siblings, it doesn't make sense to throw them all out, but it might make good sense to reduce the nest size and get a bit more parental investment, while also ensuring its genes live on in most of its siblings.

Having spent a lot of time discussing altruistic behavior, Dawkins rounds out his discussion of selfish behavior by adding some "diabolical" strategies, such as fratricide (killing one's siblings) to the picture. Even though it seems like an animal is going against its genes by killing a sibling (who have half their genes in common), it happens when the long-term genetic payoff is better than letting that sibling live. Dawkins wants to emphasize that all behavior—however good or bad it seems—has the same root cause: selfish genes.

There is often a conflict of interest between parent (who's optimal clutch size might be five) and child (who's optimal clutch size might be four). Dawkins wonders who tends to win in conflicts between parents and children. Alexander thinks parents always win this fight, because a selfish chick will grow up to pass on selfishness, meaning their chicks will kill each other, and fewer survive each generation. Eventually this trait would die out, meaning the parent's optimal clutch size wins out overall. Dawkins thinks there is more of a situational give and take between mother and child. Mothers are bigger and stronger, but children can manipulate situations by pretending (to be hungry, for example). He thinks a compromise emerges between the optimum situations for the mother and the child.

Dawkins names another theorist (Alexander) who also explains behavior in terms of natural selection among genes. As before, Dawkins and Alexander disagree on specific details, but share the same general view that genes acting in the interest of their own survival are the explain. By naming another scientist who agrees with his big picture, Dawkins shows that the gene's eye view of evolution has weight among scientists. Dawkins also implicitly implies that even if readers dispute details of his explanations, they can still accept the big picture view that genes evolve, and only selfish genes survive natural selection.

Dawkins reminds the reader that he is not advocating this kind of behavior, nor saying that anybody does it on purpose. He's only talking about the types of behavioral traits that tend to survive in the gene pool. He thinks this means that humans need to teach children altruism, because selfishness is favored by nature.

Reiterating that there is no altruism in nature, Dawkins reminds the reader that humans can and should teach their young to be selfless. Humans behave according to cultural ideas as well as biological programming. He thinks altruism is a cultural idea.

CHAPTER 9: BATTLE OF THE SEXES

Trivers argues that sexual relationships are shaped by mutual mistrust and mutual exploitation. Dawkins agrees, because from a genetic perspective, mates are not genetically related. Mates share an investment in their child (which has half of each parents' genes), which demands a certain amount of cooperation, but overall it would be a smart strategy to trick the other parent into "caring" for existing children, and focus on more mating, to get more genes into the gene pool.

Dawkins is shifting from describing individuals that are genetically related (such as parents and children), to individuals that aren't. He starts with mates which are not genetically related, but have a potential shared genetic investment in common (their children). Dawkins wants to run through some of the behaviors in the mating game to show that even here, selfish genes account for what happens.

In order to address selfishness and altruism between mates, Dawkins first needs a way of characterizing the sexes. The problem is that many species don't have the same markers of sex as humans do. For example, male frogs don't have penises. The only consistent difference across species is that the egg is larger than the sperm. Dawkins decides to call organisms with small sex cells "male" and organisms with large sex cells "female."

Dawkins wants to show that selfish genes explain all mating behavior in the natural world. First, he needs a uniform way to address a diverse array of mating practices. The only commonality across species is that mating happens with a small sex cell (which he'll call male) and a large sex cell (which he'll call female). These two types of cells are distributed (and united during mating) in diverse ways depending on the species, but ultimately, mating in all species involves both.

The first thing that's obvious from the get-go is that larger sex cells provide more nourishment for the embryo. Even at this stage, the female contributes more. Dawkins says that "female exploitation begins here." It's likely that natural selection favored large female sex cells, since more nourishment gives the embryo a good start. If so, it would have made good sense for the male sex cells to evolve to be as small as possible (effectively making more small sex cells than few big ones). In this sense, eggs are playing an "honest" behavior strategy and sperm are "exploiters."

Dawkins thinks the size discrepancy between large (female) sex cells and small (male) sex cells explains why "female exploitation" happens: even from the start, the female cell has already invested more in the potential offspring. Genes that create small sex cells effectively "cheat." Interactions between individuals often involve honest and cheating strategies. Dawkins will explain these at length to debunk the group selection idea that some organisms are inherently "honest" (altruistic) and others are inherently "exploiters" (selfish). He means that discrepancies in behavior strategies will arise, but genes will always trigger behavior that gives them the best chance of surviving, even if they start out at a disadvantage.

Dawkins believes that group selection theorists run into problems when sex ratios come up, since it's obvious that only need one or two males are needed to get a whole population going. In many animal populations, only some of the males actually mate. For example, only 4 percent of male elephant seals mate. So, why don't the other males kill themselves to save resources for the good of the species?

Dawkins wants to show that the group selection view can't explain why there are equal sex ratios in most (if not all) populations. If altruism did exist, it would make sense for non-mating individuals to commit suicide for the good of the species, but they don't. So, the group selectionists must be wrong.

Dawkins believes that selfish genes provide a better explanation for why there are roughly equal numbers of males and females in a species. R. A. Fisher's research explains sex ratios from the gene's eye view. Suppose that among elephant seals, there's a trait for having more daughters than sons. This would work for a while, as the group would survive even with only a few sons doing all the mating. Daughters would become very common. But then sons would have an advantage, since they'd be doing most of the mating. So, the gene for having sons would spread through the group and become numerous. Ultimately, an equal ratio of males to females ends up being the evolutionarily stable state.

Fisher gives a gene's eye view explanation of sex ratios, which Dawkins uses to show that the selfish gene accounts for these as well, and is thus a better account of evolution than the group selection view. When sex ratios are uneven in a population, they swing back and forth with each generation because each sex has a genetic advantage when their numbers are limited. The ratio that stays consistent over multiple generations (or, the evolutionarily stable state) is equal numbers of males and females.

Dawkins recalls that he is thinking of individuals as **survival machines** for their genes. Each individual wants to mate and pass on as many genes as possible. It makes good sense to trick one parent into caring for existing children while the other keeps mating. Dawkins thinks it's harder for females to trick males because their sex cells are larger, meaning they have already invested more in the embryo than males. Females have more to lose if the offspring doesn't survive, especially if the female has incubated an embryo in her body. This means that males face more evolutionary pressure to desert their mates.

Dawkins decides to address situations in which parents abandon their young. According to the gene's eye view of evolution, males have less to lose from shirking the responsibility of childcare, since smaller sex cells mean a smaller energy investment per child. Yet in nature, many different childcare practices exist. Dawkins runs through a few of these to show that neither group selection nor altruism play a role in these dynamics. Rather, they exist because successful selfish genes are able to program their survival machines with strategic traits that even the balance.

What about a deserted female, however? Trivers thinks it would make sense for her to trick another male into thinking the baby is his. He thinks this is why male mice evolved to secrete chemicals that trigger a miscarriage when inhaled by a female carrying another mouse's embryo. Similar counter-strategies include male lions murdering existing cubs when joining a pride, and males who prefer long courtships before mating, just in case the female is already pregnant.

Consider male mice who secrete chemicals that kill other mice's embryos in their female mates. Clearly, this makes no sense from the group selection view, since the behavior seems to inhibit (rather than help) the success of the group overall. It makes perfect sense from the gene's perspective however, since the male mouse's genes are the only things to benefit from this behavioral trait.

Trivers also believes that female birds require extensive courting because it makes males less likely to desert them after mating. The male has to secure territory and build a nest. With an increased investment in the courtship, he has more to lose by walking away. Dawkins disagrees, because he doesn't think prior investment makes males more likely to invest more in the future, especially if there are other females in the group who demand less of their mates.

Trivers argues that courtship rituals involving a lot of labor for men benefit aren't altruistic. Rather, females only mate with males who have increased their labor before mating to even out the balance of the female's extra investment in childbearing. Dawkins disagrees, but once again indicates that other scientists support the idea of denying altruism, even if they don't agree on specific details.

Dawkins draws on Maynard Smith to work out the likelihood of females being "coy" (require a lot of courting) versus "fast" (easy to court), and males being "philanderers" (likely to desert his partner) versus "faithful" (likely to stay and care for future offspring). If one does the math, looking at the genetic costs and benefits of each strategy over a few generations, it turns out that the evolutionarily stable state is reached when most females act "coy," and just over half the males act "faithful," or when females act coy most of the time, and males act faithful more often than not.

Dawkins uses Maynard Smith's mathematical calculations to address flirting and cheating in nature. He doesn't think it's because some individuals are inherently more altruistic than others. The actual balance of flirty ("fast") females, aloof ("coy") females, "faithful" males, and cheating males ("philanderers") exists because that balance becomes evolutionarily stable. The ratio that exists in nature enables all of those genes to survive for generations to come, in the exact same proportions.

Dawkins speculates that it pays off for females to be coy in ways that enhance egg cultivation. He thinks this is why "courtship feeding" happens. In many bird species, the male has to feed the female for a length of time before mating, which gives her (and her sex cells) energy for future embryos. Courtship feeding happens among insects and spiders too. For example, it's smart for a praying mantis to feed his mate before copulating, because it reduces the chance of her being hungry and eating him after mating.

Dawkins argues that even courtship feeding, in which males feed females prior to mating, is not altruistic. In birds, the female's selfish genes benefit from mating with males who feed them, since it makes their embryos more likely to be well-nourished and survive to reproduce. In praying mantises, the male's genes benefit from feeding his mate so that she doesn't eat him when mating.

Dawkins wonders why there are some species in which males look after embryos or children. This happens a lot in fish. He concludes that since fish spray their sex cells into the water (where they combine), and embryos aren't grown in the female's body, it pays for the female to spray her cells near a male and then desert him.

Another possible case of altruism in nature arises when males look after embryos or children, which is common among fish. Dawkins argues that male fish don't take on that responsibility to be nice. Rather, the mating procedures give females an advantage in shifting the burden of childbearing. Once again, selfishness (and not altruism) explains this tendency among fish.

Many people think females are drawn to mates for reasons like having long legs to escape predators, or strong arms to carry food. Darwin thought this was incorrect, and Dawkins thinks so, too. He thinks females want sons who are likely to breed and pass on their genes. This means older mates are better (because it's clear they live long and can breed more), and attractive mates are best (since inherited attractiveness will help their own sons mate later on).

Scientists often disagree on what motivates sexual attraction. Dawkins thinks the answer is very simple: being good looking increases one's chance of mating and passing on one's genes. This seemingly superficial explanation once again puts a selfish gene at the center of the explanation: the gene for attractiveness.

Zahavi has another explanation. He thinks that some males have "handicaps" (like large antlers, or long flowing tails) to show females they are strong and powerful despite these handicaps, meaning they're more attractive overall. Dawkins finds Zahavi's explanation a bit ridiculous. Dawkins thinks it's clear that strong males mate with females because they win fights with challengers who try to move in on their "harems." Dawkins believes he's shown that selfish genetic motivations underlie a host of mating behaviors, including monogamy, promiscuity, and harems. He wants to show that this is true for other aspects of mating too.

Dawkins discusses some of Zahavi's alternative genetic explanations for attractiveness, which he disagrees with. This disagreement implicitly invites the reader to think about explanations they might provide themselves, which draws them further into engaging with the gene's eye view of evolution. Meanwhile Dawkins moves on to address even more behaviors in the mating game, to show that gene survival is behind all of them.

Birds with brightly colored feathers attract mates, but birds with "drab" feathers blend in and hide from predators. Dawkins thinks that both kinds of genes compete, and what actually happens is a compromise. Females have "drab" feathers and males have colored feathers. Eggs are a scarcer resource, so females don't need bright colors to nab a mate, but muted feathers help disguise them from predators. Males, however, only need to live long enough to mate to keep their colored feathers in the gene pool, even if they are eaten by predators shortly after. Females who are "fussier" about choosing a mate have a smaller chance of accidentally breeding with the wrong species (for example, with a donkey instead of a horse) and birthing sterile offspring, which stops their genes from living on in the gene pool.

Dawkins explains that eggs are rarer than cells, meaning that generally, males compete for female mates, and not vice versa. In males, the genetic benefit of blending in with one's surroundings to hide from predators is outweighed by the benefit of standing out to attract a mate. Similarly, among females, the genetic benefit of being pickier about mates is higher than mating more freely. In each case, the behavior persists because it's the strategy that keeps the most genes alive. Dawkins believes his thorough examination of mating behaviors shows that the strongest and most consistent explanation for why they happen is selfish genes.

However, the oddest mating habits in a species actually arise in humans. Human women tend to beautify themselves and act as if they are competing for male mates. This is the opposite of what normally happens in nature.

The biggest anomaly, it seems, occurs in humans, in which women compete for male mates. Dawkins is implying that something other than biology explains this tendency. Later, he will argue that culture accounts for many human behaviors, especially when they don't line up with what goes on in nature.

CHAPTER 10: YOU SCRATCH MY BACK, I'LL RIDE ON YOURS

Dawkins has considered aggressive, parental, and sexual behaviors among **survival machines**. Now, he wants to address social insects, understand why animals live in groups, and try to make sense of reciprocal altruism, meaning the principle of "you scratch my back, I'll scratch yours."

Dawkins wants to cover as many aspects of animal behavior for as many species as possible, to show that in each case, the selfish gene explanation fits. He thinks this will make his view more compelling to the reader.

Hunting in a group makes good "selfish" sense, since it makes catching prey easier. Dawkins borrows another explanation from Hamilton, who thinks that running as a herd also has selfish motivations. Animals on the edge of a herd are more likely to get eaten by predators. It's a good "selfish" strategy for animals to clump into herds and try to get in the middle to protect themselves from predators.

Dawkins argues that animals tend to function in groups because it makes it easier to catch prey, or escape from predators, which keeps the individuals in a group alive, and their genes in the gene pool. He implies that just because animals often function in groups, it doesn't mean the group is evolving as a unit.

Birds sometimes call to warn other birds there's a predator nearby. This seems problematic, because it puts the calling bird at greater risk of being eaten. It's been such a problem for Darwin's theory of evolution that scientists have thought up all sorts crazy explanations for bird alarm calls, including Trivers who gives five different explanations. It's likely, for example, that nearby birds are related, so birds protect their genes (in their relatives) when they sound alarms, keeping that trait in the gene pool.

Bird calls that warn about nearby predators make sense for group selectionists: the individual bird altruistically puts herself at risk of being eaten so the others can survive. It's harder to make sense of this behavior from the gene's eye view, which is why so many scientists have tried. As he indicates elsewhere, Dawkins says there are multiple explanations with the selfish gene at the center, just in case the reader takes issue with any of his specific examples.

Dawkins offers two explanations of his own. The noise of nearby birds might attract a predator even if one bird is quiet. So, perhaps the calling bird is selfishly trying to warn others to keep quiet. Also, if a bird just flies away when spotting a predator, he actually stands out more as a lone (and therefore vulnerable) bird. Sounding an alarm might be a way to get the whole flock to fly away, keeping the calling bird safely in the middle of the flock, and far from the predator. Dawkins concludes that warning calls have selfish motivations.

Dawkins gives two possible reasons for why birds sound alarm calls, to show that in both cases, the behavior actually helps the individual bird (and their genes) survive, even though it looks like the behavior puts them at individual risk. He implies that once again, there's no altruism in play here, despite explanations that group selectionists might give.

It's harder to explain what genetic payoffs there might be for gazelles who "stot" (bounce) to warn about predators, but draw attention to themselves in the act. Ardrey thinks this is altruism for the good of the group, but Zahavi disagrees. Zahavi thinks stotting warns predators that the gazelle is so fit and strong that she can stot around and still not get caught.

Dawkins addresses the similar case of gazelles who stot when predators are nearby, despite this action slowing them down. Once again, theorists like Zahavi suggest that selfish genes and not altruism can provide a plausible explanation.

"Kamikaze" bees die when stinging, which looks on the surface like altruism for the good of the colony, but Dawkins disagrees. Most bees in a colony are sterile, and only sterile bees sting, so there's no genetic loss involved. In fact, he thinks the colony acts more like one individual. It seems to have collective consciousness, and a communal stomach, for example. Dawkins thinks the queen represents reproductive cells, and worker bees function as organs like the heart, muscles, liver, and so on. He speculates that the death of a sterile bee is like a tree losing a leaf.

It's a bit more challenging to show that bees who die when they sting are selfish, since they definitely die at the expense of others in their group. Dawkins argues that an individual bee isn't a survival machine—rather, a whole colony collectively functions as one survival machine. A "kamikaze" bee's death is therefore analogous to losing a non-reproductive part of one's body, such as an arm. As long as the reproductive organs (here, the queen) still function, all the genes in the survival machine (colony) will keep replicating.

Another way to think about social insects is to invoke the "bearing" and "caring" dichotomy. Reproductive insects in a colony are "bearers," and worker insects are "carers." Since they are all genetically related, this isn't altruistic behavior, but selfish behavior. This division of labor keeps all their genes in the gene pool. Hamilton discovered that "the Hymenoptera" (insects including ants, bees, and wasps) determine sex differently. Unfertilized eggs become male worker bees, meaning they actually share all of their genes with the queen and her offspring, so from a genetic perspective, protecting the reproductive bees is better than protecting themselves.

Similarly, when worker insects perform a lot of labor in the colony, it's for the purpose of keeping the queen alive and reproducing. The workers don't act altruistic. Rather, they do what's in the best interest of their genes, which are replicated as long as the reproducing insects survive. Since worker bees (males) have all of their genes in common with the reproductive bees (females), helping the females focus on reproducing actually helps their genes the most.

Inspired by Fisher's research, Trivers and Hare calculated ideal sex ratios in hymenopteran colonies. There is a potential conflict of interest because workers benefit from having more female (reproductive) insects in the colony to pass on their genes, but the queen benefits from having equal males and females, some to reproduce, and some to keep the colony (and the reproductive bees) fed and protected. In ants, the workers would win out, except ants often take unknowing slaves into their colonies. The adaptive strategies among "slave-making" queens and "slave-taking" queens play out such that reproductive ratios end up closer to what is optimal for the queen: equal males and females.

Conflicts of interests within insect colonies—say, over sex ratios—don't imply that worker ants give up their preferred ratios to be altruistic toward the queen. In ants, for example, some insects get stolen and taken to other colonies as slaves. When the behavioral strategies of all the insects involved are factored in, equal sex ratios become evolutionarily stable states, meaning that equal sex ratios persist because they're in the best interest of the genes involved.

Dawkins thinks an art farm (or hymenopteran farm) functions like a gene farm. The queen is farmed for her eggs, and the whole colony is organized to facilitate genes being passed on, packaged in reproductive ants.

Dawkins imagines a hymenopteran colony functions like a single farm or factory, oriented toward producing one product: their genes. He uses this metaphor to help the reader think of the colony as a single survival machine operated by selfish genes, rather than a group containing some altruistic individuals.

Dawkins starts thinking about symbiotic relationships in the natural world. Many ants feed fungi in order to later farm them, for example. They also milk aphids while protecting them from predators. Lichens are "double organisms"—an intimate symbiosis between algae and fungi. The relationship is so close that lichens seem like individual plants. Humans also contain tiny bacteria called mitochondria. Without mitochondria, we would die. And without us, mitochondria would die. Similarly, viruses are parasitic replicators (DNA surrounded by protein) that have bypassed the need to be transferred through reproductive organs. They just hop around from body to body.

Dawkins turns to symbiotic relationships in nature, which he hasn't addressed yet. He wants to show that for cases of interspecies cooperation—such as between bacteria and humans, or ants and fungi—the same explanation always applies: groups are not evolving, and there's no altruism in play. Rather, genes are competing in a selfish game of survival, and the ones that win out in natural selection explain all behaviors that are observable in the natural world.

Symbiotic relationships, or "associations of mutual benefit" evolve if each partner gets more out the relationship than they put in. Group selection theorists would consider cooperation *between* species separately from cooperation *within* species, but Dawkins thinks there's no need for that. He wonders if reciprocal altruism (for example, scratching each other's backs to get rid of parasites) has selfish motivations as well. Darwin (and later Williams) thought that reciprocal altruism could evolve in populations that were able to recognize and remember each other.

Dawkins thinks that both symbiotic relationships (cooperation between *species) and reciprocal altruism (cooperation* within *a species) make sense when explained from the gene's eye view: they happen because the genes for those behaviors has won out in natural selection, especially when one factors in the ability to recognize and remember other individuals. Dawkins thinks it's a strength of his view that unlike group selectionists, he doesn't need many different explanations to account for a variety of animal behaviors.*

Trivers looked at this puzzle too, and used the Prisoner's Dilemma from game theory (the mathematics of strategic interactions) to solve it in 1971. Trivers worked out that in a population with "suckers" (who always pick parasites off others), "cheats" (who accept help but don't reciprocate), and "grudgers" (who pick parasites off but remember cheaters and don't help them next time around). Depending on the starting ratio of the population, the group will evolve to be nearly all cheats (and eventually shrink in numbers or die out), or mostly grudgers. Both are evolutionarily stable strategies.

The Prisoner's Dilemma is a theoretical example that calculates the odds of two individuals cooperating with each other when they don't know what the other person will do. Both individuals benefit from cooperating. However, it's be a safer bet to be selfish, because the individual loses out the most when they cooperate, but the other person doesn't (or, they act like a "sucker").

Trivers also looked at "cleaner-fish," who have a symbiotic relationship with larger fish. Cleaner fish get their food by nibbling parasites off large fish, and large fish in turn get cleaned. This also seems like reciprocal altruism. The large fish could eat the cleaner fish after they've been cleaned but they don't. Similarly, the cleaner-fish could take bites out of the large fish and swim away, but on the whole, they don't either. Dawkins suggests that because symbiotic cleaning happens at fixed places in the ocean for each fish species, reciprocal altruism based on some form of recognition might have evolved.

Dawkins describes another example of cooperation among fish to show that "reciprocal altruism" makes good selfish sense. The cleaners and the large fish aren't nice just for the sake of it. Rather, the most stable strategy arises when the fish don't exploit each other. If one side cheats, the exploited fish will likely remember and refuse to participate in the future, which means that both lose out: one on the mutual benefit of easy access to food, and the other on easy access to parasite removal.

Trivers also thought that feelings like sympathy, guilt, envy, and gratitude evolved to help humans cheat and detect cheats. Dawkins decides to let the reader speculate about that one on their own.

Trivers implies that many human emotions exist because they help humans to feel strongly about the people who exploit them. Trivers implies that even humans (who understand the concept of altruism) play the "grudger" strategy. They tend to be nice at first, but not again if the kindness is not reciprocated.

CHAPTER 11: MEMES: THE NEW REPLICATORS

Dawkins hasn't talked much about humans yet. One of the reasons he uses "**survival machine**" instead of "animal" is because it includes plants and humans, so he thinks everything he's said so far applies to humans. Still, he wonders if there's something going on with humans that makes us different from other beings on earth. Dawkins thinks there is. "Culture" makes humans different, because "cultural transmission" gives rise to evolution, as well. If Geoffrey Chaucer tried to have a conversation with an English-speaking person today, Chaucer wouldn't make any sense. This means that language evolves by "non genetic" means. Dawkins thinks language evolves much faster than genes do.

Dawkins thinks that human behavior doesn't always line up with other species because there are two forms of altruism going on in humans: the biological evolution of our genes, and the cultural evolution of our ideas. Cultural evolution might have an even stronger effect on our behavior, because it happens at a much faster rate than biological evolution. Dawkins expands his view here to show that altruism might come from cultural evolution, and that evolution doesn't only happen among genes.

Cultural transmission happens in other species too. P. F. Jenkins studied saddleback bird songs in New Zealand, and discovered that their songs aren't inherited, but learned, and slightly modified (sometimes by accident) by each generation. He called this a form of "cultural mutation." Dawkins believes that, of all the species in the world, humans really show what cultural evolution can do.

Dawkins discusses Jenkins to show that cultural evolution is a plausible theory because there's also evidence of it in other species. Nonetheless, he still thinks humans are the best example to address, because there are many more cases to draw on from the human context.

Language, fashion, food, customs, art, architecture, engineering, and technology are all examples of cultural evolution. They function like really sped-up versions of genetic evolution. Other theorists have noticed this too, including philosopher Sir Karl Popper, geneticist L. L. Cavalli-Sforza, anthropologist T. F. Cloak, and ethologist J. M. Cullen. They argue that cultural practices have "biological advantages." For example, tribal religion is thought to improve unity in a group, which is important for pack hunters. Dawkins, however, believes that for the case of culture, it's necessary to throw out the "gene" as the basis of evolution. He thinks this is more Darwinian than the other explanations, because evolution is so pervasive that there's no need for it to be restricted to genes.

In order to show that cultural evolution is a second kind of evolution, Dawkins needs to show that it doesn't just collapse into a form of biological evolution (as many theorists in different fields suggest). Dawkins wants to convince the reader that departing from the biological view of evolution is a good strategy, so he implies that Darwin would be on his side if he were alive. Dawkins believes evolution is such a good theory that it explains what goes in many contexts, whether or not genes are involved.

Dawkins recalls that what makes genes special is that they are replicators. It might well be that on other planets based on silicone instead of carbon, or ammonia instead of water, or electronic circuits instead of organic compounds, replicators wouldn't be DNA, but something else. If there's any consistent law about life in the universe, it's that "all life evolves by the differential survival of replicating entities. The gene, the DNA molecule, happens to be the replicating entity that prevails on our own planet."

Dawkins reminds the reader that he chose genes as the basis of evolution in nature because genes can replicate (copy) themselves, while species can't. It's the act of replicating that's actually important, and genes only matter because they happen to be replicators in nature. In fact, Dawkins thinks anything that's capable of replicating can evolve, whether the "thing" is an idea, a gene, or some alien substance.

One need not look at alien planets to figure this out, because "a new kind of replicator has emerged on earth." It's still in "infancy," floating around in **primeval soup**, but it's happening at an astonishingly faster pace than genetic evolution. The new soup is "the soup of human culture."

Dawkins reframes cultural practices in evolutionary terms—as replicators competing for resources in primeval soup—to emphasize that the processes by which ideas develop in a culture match those that genes go through when evolving in nature. The similarity implies that evolution is happening in both cases.

The replicator in the soup of human culture is something that can rapidly imitate itself. Dawkins decides to call this "unit of imitation" a meme (adapted from the Greek *mimeme* Examples of memes include catchy tunes, phrases, images, fashions, and ideas.

Dawkins uses the term "meme" to capture a unit of cultural evolution. He creates this word from the Greek word mimeme *(which means "imitation," and thus captures the function of copying or imitating). Dawkins also thinks "meme" sounds a bit like "gene," and he wants to emphasize the similarity between these two entities as replicators.*

Genes propagate themselves in the gene pool by hopping from body to body via eggs and sperm. Memes propagate themselves in the meme pool by hopping from brain to brain, by a process of imitation.For example, if a scientist reads about a good idea, he'll discuss it with colleagues and students, maybe write about it in his research articles, and mention it in his lectures. If the idea catches on, it's "propagating itself, spreading from brain to brain."

Memes are replicators because it's possible for copies of ideas to exist in multiple people's brains. When an idea—such as a scientific theory, a trendy hairstyle, or a new slang word—spreads, more and more people talk about it, and thus more copies of that idea are stored in more people's minds.

Another meme that's very successful is the "God" meme. It's a very old idea that has stayed in the cultural meme pool for a long time. Dawkins thinks memes that survive over the course of cultural evolution have strong psychological appeal. They satisfy deep questions in our minds, in some way.

Dawkins thinks the idea of God is a meme that has fared well in the cultural gene pool. He implies that successful memes are able to stay in the cultural meme pool for a long time (like genes that keep existing over generations of evolution).

Some theorists want to know why the "God" meme has psychological appeal, and whether there's a genetic reason underlying it, but Dawkins thinks that's a bit of a stretch. He thinks that for thousands of millions of years, the only replicator on Earth was DNA, but when the conditions arose for a new replicator, there's no reason it has to depend upon the old one. He says that "biologists have assimilated the idea of genetic evolution so deeply that we tend to forget that it's only one of many possible kinds of evolution."

Dawkins thinks it's not necessary to seek biological or genetic reasons for certain memes. He's reminding the reader that cultural evolution is a distinct form of evolution that doesn't collapse into genetic evolution. Genes aren't part of the picture in cultural evolution, because they compete with other genes in the domain of nature. Memes only compete with each other, in the domain of culture, and other replicators will compete in their own specific contexts.

Memes, like genes, have varying success in the overall pool. Some memes have "brilliant" short-term success, but then fade away or die out (say, popular songs). Other memes survive a lot longer (say, Jewish laws). Memes also "mutate" in a sense: every time someone retells an idea, they tell their own version of it. In fact, mutation seems continuous with memes, whereas gene mutation is not always continuous across generations. Memes can be long or short, just like genes—they could be a whole song, or just the catchiest part of it. These become slightly different replicators (just like genes).

Dawkins emphasizes parallels between the way memes spread and the way genes spread, to stress that both can be described in exactly the same way. Some memes do well in the short term, but don't persist (aren't stable) in the long term. More successful memes survive over generations. An idea "mutates" when it's remembered slightly differently, or just remembered in part, which creates a slightly different replicator.

Dawkins wonders if memes compete for survival in the way that genes do—he thinks they do. He asks the reader to imagine the human brain is a computer. A computer has a fixed amount of memory, meaning some things have to be deleted to make room for other things. Memes are competing for "memory" or "attention" in the human brain. They also compete for television airtime, billboard space, and library shelf space.

Dawkins has shown that differential entities exist. (replicating ideas that can be remembered slightly differently by different people). He now argues that finite resources exist. Humans can't remember everything, and don't believe conflicting ideas, so we have a finite amount of brain space that ideas compete for. This description shows that the conditions are ripe for natural selection to take place.

Memes survive for various reasons. Fear makes ideas stick, for example, which is why religion has had such longevity as a meme. Dawkins also thinks that "[cultural] selection favors memes that exploit their cultural environment to their own advantage." Dawkins suggests that married priests have less time for preaching, which may be why celibacy is an effective meme in the Catholic religion. Memes can live on intact in ways that genes don't. Genes tend to separate into different **survival machines**, meaning their colonies don't stay intact. But memes can live on intact for much longer. Dawkins thinks, for example, about memes that Socrates wrote, or Leonardo da Vinci painted, or Copernicus said.

Just as genes that perform well in the gene pool when their survival machines function best in the natural environment, memes are successful if they perform well in their cultural environment. Although genes shuffle in and out of different combinations in their survival machines, ideas don't need to do this. In both cases, however, long-lasting replicators (whether they be genes or memes) perform well because they survive in the long-term picture. Both cases exemplify Darwin's principle of "survival of the fittest."

Another thing that makes memes different from genes is that human brains have the capacity for conscious foresight. Genes don't—they are "unconscious, blind replicators." Even though humanity's genes (and memes) are "selfish," we have "the power to defy the selfish genes of our birth, and, if necessary, the selfish memes of our indoctrination." In other words, we have the capacity to cultivate altruism, through memes. Humans are unique on Earth because "we have the power to turn against our creators. We alone on earth, can rebel against the tyranny of the selfish replicators."

A crucial difference between genes and memes, however, is that genes aren't conscious— they are only successful in the gene pool if they happen to program their survival machines to perform well in their environments. Dawkins emphasizes this point to show that humans have more power in the case of memes. Altruism is a meme that we can perpetuate by choice, and if we're altruistic, or want to be more altruistic, it's the culture that can make this happen, not genes.

CHAPTER 12: NICE GUYS FINISH FIRST

"Nice guys finish last" is a common saying. But Dawkins thinks there's also a sense in which nice guys finish first. He thinks about birds who are "grudgers" (those that pick parasites off other birds, but remember the ones that don't return the favor and ignore them the next time around). That strategy actually beats out the "cheat" strategy (accepting help with parasites but not reciprocating). Dawkins thinks the "grudger" is the kind of "nice guy" who "finishes first." This is the individual who engages in "reciprocal altruism." Dawkins agrees with Robert Axelrod and Hamilton that many wild animals are "engaged in ceaseless games of the Prisoner's Dilemma, played out in evolutionary time," which explains why nice guys finish first.

Dawkins revisits reciprocal altruism, because he wants to convince the reader more fully that there definitely isn't altruism in nature. He uses the Prisoner's Dilemma (which calculates optimal outcomes between individuals who interact without knowing what the other person will do next) to prove his case. The Prisoner's Dilemma shows that the individual's genes benefit more when the individual is nice at first. Dawkins thinks the phrase "nice guys finish first" captures the sense in which altruistic behavior is underscored by selfish genes.

The Prisoner's Dilemma is a strategy game in which two people each have two cards. One card says "cooperate" and the other says "defect." Both players have the same cards. Each chooses one card and puts it face-down on the table, and the cards are revealed at the same time. If both people play "cooperate," they each win $300. If both people play "defect," they each pay a $10 fine. If one person plays "cooperate" and the other plays "defect," the person who plays "cooperate" has to pay $100, and the person who plays "defect" wins $500.

In the Prisoner's Dilemma game, two friends are interacting, but neither knows what the other one will do. They both win a lot of money if they "cooperate." If both "defect," they each lose a bit, but not very much. However, if one of them cooperates when the other defects, the person who cooperated loses everything, and the defector wins a lot (but only a bit more than if they both cooperated). The game is set up to test a person's likelihood of cooperating (or being altruistic).

Even though mutual cooperation is the best strategy (both people win money), most people will play "defect," because the risk of being the only one to cooperate is too high. This is why the game is called a "dilemma." The most logical thing to do is defect—it won't yield the best potential outcome, but it's the least risky strategy.

The "dilemma" arises because cooperating is the best strategy for both players combined (both win). But when an individual cooperates, there's a chance that the individual will lose everything if the other person defects. The risk of a big loss makes most people defect, even if they'd prefer to cooperate. In other words, the only way to avoid a big loss is to be selfish.

There's another version of the game called the "Iterated (Repeated) Prisoner's Dilemma." In this version, the same players play the game over and over again, meaning they know what cards the other player chose in the previous round. Dawkins thinks the birds who were picking parasites off each other's backs were playing the iterated Prisoner's Dilemma, since they picked parasites multiple times and remembered the other birds' strategies.

The best strategies to play change a bit when the game is repeated (iterated) and each player knows what happened in the last round. Dawkins thinks the iterated game comes closest to what happens in nature, because many organisms can remember who helped them in the past and who didn't, so this is the one he'll use to explain why reciprocal altruism (or mutual cooperation) is ultimately selfish.

Axelrod ran a competition where he programmed a computer to play all the possible strategies in the iterated Prisoner's Dilemma (including one strategy that was simply "random") 200 times. There are 15 possible strategies. It turns out that the winning strategy was "Tit for Tat," meaning be nice on the first round, and in the next round play whatever card one's opponent played in the previous round.

The best performing strategy when the game is repeated many times is "Tit for Tat." Since it entails acting nice at first, then doing what one's opponent does, Tit for Tat is somewhat similar to the "grudger" strategy in nature. Tit for Tat shows how being "nice" at first can yield the best selfish payoff.

Axelrod ran the "Tit for Tat" strategy against a lot of other strategies, including some very similar ones. Two similar strategies are "Naïve Prober" (which is basically "Tit for Tat" with a random extra "Defect" thrown in now and again), and "Remorseful Prober" (which will randomly play "Defect," but then play "Cooperate" on the next round). Dawkins calls these "nasty" strategies because they involve defecting first. Tit for Tat, however, is a "nice" strategy, because it only defects in retaliation. It turns out, that when ranked, the eight best strategies were "nice" strategies (in which the player never defects unprovoked), and the strategies that trailed behind were "nasty" strategies (in which the player does defect unprovoked, in some way or another).

Axelrod shows that even upon further testing, all the strategies that involve acting "nice" at first give players better outcomes than the strategies that begin with acting "nasty." Dawkins stresses this to show that acting nice at first in nature (as grudgers do) is actually the best way for an individual to maximize their winnings in the game of life. This "nice" behavior happens in nature because the genes that program their survival machines to act that way are the most successful at keeping their survival machines alive.

"Tit for Tat" is also a forgiving strategy: one only play the card one's opponent played on the previous round. The "grudger" strategy that birds play when picking parasites off each other, in contrast, is unforgiving. The bird remembers that another bird didn't help them for the whole game and never helps them again, even if the cheating bird changes its mind and helps the grudger. It turns out that the "grudger" strategy ranked next to last in Axelrod's simulation. Dawkins thinks this means that the best strategies are both "nice" and "forgiving."

In fact, "Tit for Tat" shows that being more altruistic than grudgers are will yield the best results. Grudgers never help someone who betrayed them once before, but Tit for Tat, is more forgiving: individuals will switch back to being nice if the other player does. Dawkins implies that individuals who are more forgiving (altruistic) in nature would actually be the most successful.

Axelrod called "Tit for Tat" a "robust" strategy. Dawkins calls it an evolutionarily stable strategy. Interestingly, "Tit for Tat" doesn't win in an environment where most other strategies are nasty. Dawkins thinks this means that evolutionarily stable strategies work when there are a lot of others who act in similar ways. This is exactly what happens in nature, because winning strategies produce offspring that inherit similar behavior tendencies.

Dawkins stresses that Axelrod's research is a good model for explaining behaviors in nature, because it also explores scenarios where the players are mostly "nice" or mostly "nasty." In nature, too, the base disposition of the population will vary depending on the behavioral tendencies that are inherited in a particular population.

Axelrod ran his Prisoner's Dilemma game multiple times. Dawkins thinks each round of games is analogous to a generation. When multiple rounds are played it turns out that the winning strategy is whichever more or less "stable" one is dominant first. If "always defect" is played often, and early in the game, it will dominate and become the evolutionarily stable strategy.

The Prisoner's Dilemma shows that different behavior patterns can become evolutionarily stable strategies. The population will settle into a pattern that's based on acting selfishly all the time, or acting nice at first. There's no case, however, in which always being nice (or being purely altruistic) will persist from generation to generation.

Dawkins wonders which strategy (between "Tit for Tat" and "always defect") wins out in real life, if both are stable. "Tit for Tat" tends to do well when other people play the same strategy. He decides that since individuals tend to live near their kin, it's likely that if one person tends to play "nice," their genetic relatives will too, and "Tit for Tat" prevails. An "always defect" family would stay that way, but fair badly in the long run.

In the natural world, populations either "cooperate" and act nice at first, or "defect" and act selfish all the time. However, in the long run, the selfish populations are more likely to die out. Dawkins is implying that acting nice at first (or being somewhat altruistic) is actually the most selfish thing to do in the long run.

Games are either "zero sum" games (meaning one side wins and the other loses), or "nonzero sum" games (meaning both sides can win). Football, chess, rugby, and tennis are all zero sum games—usually there's one winner and one loser. Dawkins thinks that many situations in nature are nonzero sum games. If both sides cooperate, they can both win, which explains how "cooperation and mutual assistance can flourish even in a basically selfish world."

The Prisoner's Dilemma, like nature, is a "nonzero sum game," meaning both sides can win. Dawkins reiterates that when mutual cooperation does happen in nature, it only "flourishes" because both sides win big in this scenario. Again, what looks like altruism is explained in terms of the selfish payoffs to those interacting.

Dawkins talks about times during World War I when German and British soldiers were nice to each other between battles, even though they were enemies in the war. One Christmas, for example, they put down their guns, drank wine, and celebrated together on the battleground. Dawkins wonders if niceness can evolve in nature in the ways that Axelrod's simulation games showed (and how the World War I soldiers behaved). Dawkins concludes that it can, if the game is nonzero sum, and if it's iterated (repeated).

Dawkins thinks that organisms from different species who interact frequently can play the "cooperate" strategy in the game of nature, just as the British and German soldiers did at Christmas during World War I. The Prisoner's Dilemma shows that cooperation only happens because it's self-serving: the genetic benefit of mutual cooperation is higher than that of defecting.

For example, fig trees and fig wasps cooperate. Fig wasps pollinate fig trees, and fig trees provide nourishment for fig wasp eggs. Both sides could be exploitative (or "defect")—if the wasps lay too many eggs, or if the trees shed flowers with eggs in them—but they "cooperate" because over time (for generations) the benefit to each is higher than if they exploit each other.

Fig trees and fig wasps exemplify an iterated Prisoner's Dilemma game in which both players "cooperate." Fig wasp genes and fig tree genes both benefit more when their survival machines cooperate. Mutual cooperation is an evolutionarily stable strategy because it keeps both sets of genes in the gene pool over multiple generations.

Wilkinson's research on vampire bats indicates that the "cooperate" strategy comes up elsewhere in nature, as well. Wilkinson discovered that vampire bats who are able to feed often donate their food (which is blood) to other bats. He examined 110 donations, and found that 33 were to non-relatives. He then discovered that bats can recognize each other. Dawkins thinks these 33 examples were the "Tit for Tat" policy in action. The bats were sharing their meals in case they needed help next time. Dawkins thinks that he has shown that even in a world driven by selfish genes, "nice guys can finish first."

Wilkinson's research shows that a vampire bat who seems altruistic by sharing her food with non-relatives is actually only cooperating so that other bats are more likely return the favor in the future, which might come in handy if she doesn't score a big meal herself one night. The vampire bat's supposed altruism, once again, comes hand in hand with a hefty selfish benefit to her genes. Dawkins thinks he has covered enough examples to convince the reader that reciprocal altruism only happens in nature when the individual rewards are higher than acting selfish, meaning these actions only seem altruistic on the surface.

CHAPTER 13: THE LONG REACH OF THE GENE

Dawkins thinks that an "uneasy tension" lies at the heart of the gene's eye view of evolution. On one hand, there is a beguiling picture of genes—immortal coils, or DNA replicators—forming temporary colonies and passing through generations of mortal, throwaway **survival machines.** On the other hand, there is a coherent sense of each individual as one agent, as one living thing. Dawkins admits that in some chapters he talks about individuals as if they are agents, enacting strategic behaviors to pass on their genes, while in others he presents things from the gene's "point of view." He addresses this "paradox" at length in his book *The Extended Phenotype*. He's going to offer a short summary of that book here.

Dawkins acknowledges that the biggest challenge to his selfish gene view of evolution is how hard it is to shake off the notion that individuals are coherent selves. It's very hard for readers to mentally edit the "individual" out of the picture, even though Dawkins thinks they are nothing more than survival machines, or observable effects of genes in action. He wants to break down distinctions between individuals and others, as well as individuals and the world, to show that the concept of the individual is arbitrary, in order to make his selfish gene view seem more plausible.

Genes themselves all look alike. Their differences are only made visible by their effects on the embryos they build. These visible "effects" are called phenotypes. The phenotypic effect of one gene might be "green eyes," or "curly hair," for example. Natural selection favors genes on the basis of their phenotypic effects. Darwinians often think of the phenotypic effects as converging in one organism. A gene that makes an individual run faster keeps the individual alive to reproduce, thus benefiting all the genes in that individual. Dawkins rephrases this as "what's good for one gene is good for all."

The only way to observe a gene in action is by looking at the effects that it has on an embryo. A "phenotypic effect" is any observable trait that can be traced to a gene. An organism is really just a site where a lot of phenotypic effects converge. Dawkins wants to argue that thinking of an organism as a single entity a mistake. What really matters is the phenotypic effect of the gene.

Dawkins wonders what happens when a gene has a phenotypic effect that's good for the gene, but bad for the body as a whole. In other words, he's talking about genes that "cheat." Geneticist James Crow calls these "genes that beat the system." For example, t-genes in mice make them sterile or die young, but they also exploit the way that genes are allocated to sperm cells. This is called a "segregation disorder." When t-genes arise through mutation, they're in 95 percent of the mouse's sperm cells (instead of half). They usually cause the population to go extinct.

Dawkins first tries to dismantle the notion of an organism as a unified being by stressing genetic conflicts that go on within an organism. Some genes have phenotypic effects that damage or destroy the organism, such as t-genes in mice, which lead to sterility and, ultimately, to extinction. Dawkins raises this case to show that at the genetic level, the unity of an organism isn't important—only gene survival matters.

Dawkins characterizes biologists as people who focus on organisms and ask questions like why they group into societies, and so on. But Dawkins believes that, when one thinks about it, there's no reason to limit phenotypic effects to a particular individual. In fact, "the phenotypic effects of a gene need to be thought of as *all the effects it has on the world*." He wonders this means in practical terms. He suggests that phenotypic effects extending beyond the body can be seen in things like beaver dams, bird nests, and caddis houses. After all, these all help the genes survive too.

Dawkins argues that phenotypic effects can be observed in the environment as well as on an organism. Building a good nest, for example, also helps a gene survive, so technically the phenotypic effect is visible in the nest itself. He wants to show that the division between individuals and environments is arbitrary.

When caddis flies are larvae at the bottom of a lake, they meticulously build "mobile homes" out of tiny stones and sticks that they protect themselves with like shells. Natural selection favors caddis larvae that build the best protective homes, since this facilitates their survival and reproduction. Dawkins thinks that if a geneticist were to compare the structures of caddis houses, they would be looking at the phenotypic effects of caddis larvae genes. It makes as much sense to think of genes for "stone hardness" or "stone size" in caddis larvae as it does to think about genes for "green eyes" or "wrinkles in peas." He thinks his logic is "inescapable."

Dawkins drills deeper into the example of caddis flies to show the reader how a phenotypic effect breaks down the division between an individual and an environment. Technically, a caddis fly gene programmed the caddis fly to pick certain stones for its "mobile home," and the choice of stone also contributes to the gene's survival. Phenotypic effects are really what tests the success of a gene, and these extend beyond the boundaries of a survival machine's body.

Dawkins thinks about parasites next. Flukes (flatworms) are parasites that live in snails. They secrete chemicals that make snails build thicker shells. This is beneficial to the fluke (which is better protected inside the thicker shell), but costly to the snail (because it spends energy building a thick shell that could be saved for sustenance and reproduction). Dawkins thinks this means the fluke's genes have a phenotypic effect on the snail's shell. He thinks this happens with a lot of parasites, and it means that phenotypic effects extend to other living bodies.

Dawkins then discusses cases in which genes in one organism can have phenotypic effects on another organism's body. Genes in flatworks make snails build thicker shells. Technically, the thickness of a snail's shell is a phenotypic effect of a flatworm gene. Here Dawkins argues that the distinction between two individuals (like the distinction between an individual and its environment) is arbitrary.

If a parasite's genes are transmitted to a new host by way of the host's reproductive cells, the parasite will do everything it can to keep the host alive and reproducing. Dawkins says, "over evolutionary time it will cease to be a parasite, will cooperate with the host, and may eventually merge into the host's tissues and become unrecognizable as a parasite at all."

Many organisms contain parasites that are necessary for the organism to survive. Technically, there are two organisms, but their phenotypic effects converge in one survival machine. Once again, Dawkins wants to dismantle the idea that a body is a unified whole.

Parasitic bacteria that live in ambrosia beetles seem so essential to the beetle's reproductive processes that's hard to consider them parasitic. Like ants and bees, if a beetle egg is unfertilized it will develop into a male embryo. But unlike ants and bees, beetle eggs need to be "pricked" by something to develop into an embryo at all. Parasitic bacteria do the "pricking," which enables male embryos to develop. In a sense, the bacteria's own bodies disappear and merge with the host's bodies.

Dawkins offers a detailed example to show how thinking of a body as a single entity is wrong. Bacteria that prick beetle eggs to complete the reproductive process are very difficult to separate from the beetle itself, since the beetle wouldn't exist without the bacteria. Therefore, it almost makes more sense to think of them as one body, rather than two.

This also happens with sea anemones and algae, and with minute, free-floating DNA fragments called "viroids" or "plasmids" that splice themselves seamlessly into chromosomes in human reproductive cells (and then splice themselves out again in the embryo that's created). Similarly, venereal disease genes benefit from having their hosts copulate, because this allows the gene to spread and replicate in a new host. In fact, they even benefit from having attractive hosts (which makes copulation more likely).

Dawkins offers further examples of interactions between organisms that converge in one body in order to emphasize that this is a common phenomenon in nature. These cases imply that dividing the world up into "selves" and "others" (or different individuals) doesn't always make sense. Once again, Dawkins wants to dismantle the notion of an individual a single entity.

According to Dawkins, phenotypic effects can extend as far as across entire lakes (for example, in beaver dams), and that parasites can influence hosts from afar as well. For example, cuckoos who hatch in other birds' nests (such as songbird nests) are technically parasites. Dawkins thinks the idea of an organism having its "own body" is a "loaded assumption," because phenotypic effects can extend far beyond an organism's "own body" and external parasites (like cuckoos) can manipulate a host's behavior as much as internal ones can.

Dawkins stresses once again that genes have effects that extend well into the environment. Technically, cuckoo genes control the actions of. A cuckoo gene can have as much impact on a songbird's actions as a gene inside the songbird's own body. Dawkins thinks the concept of a body as one unified "thing" is seriously mistaken, since phenotypic effects constantly spill over into different bodies and environments.

For example, some parasitic ants invade a nest, kill the queen (either by slowly severing her head, or more efficiently, secreting a chemical that makes the workers do it), and take her place, while the unwitting worker ants tend to the parasite's brood. Similarly, some cocooned caterpillars emit noises, which make ants attach onto their cocoons and fend off predators. Dawkins thinks it doesn't make sense to talk about individuals and others. One should only be talking about genes and phenotypic effects. His central claim about extended phenotypes is that *"an animal's behavior tends to maximize the survival of the genes 'for' that behavior, whether or not those genes happen to be in the body of the particular animal performing it."*

Having addressed plants, viruses, bacteria, parasites, mollusks, mammals, and birds, Dawkins now turns to insects to show that his claim applies to the natural world as a whole. Phenotypic effects always extend beyond a single survival machine. In fact, this is such a common phenomenon that the division of the world into selves, others, and environments is inaccurate. The world should be divided into genes and phenotypic effects, because talking about individuals as discrete entities makes scientists (like group selectionists, in Dawkins's estimation) formulate mistaken accounts of evolution.

Dawkins suggests that one way to get around the problem of talking about "individuals" is to talk about replicators and vehicles. The fundamental units of evolution are things that replicate. In humans, this is DNA. They "gang together" in communal **survival machines**, or vehicles. In humans, these vehicles are our bodies. Replicators don't run around and escape from predators, they make their vehicles do that. Vehicles don't replicate, they facilitate the propagation of replicators. He thinks biologists focus on the "vehicle," but they should be focusing on the "replicator."

Dawkins thinks the mistake that group selectionists make is thinking about evolution as something that happens to "vehicles," when it's actually something that happens to "replicators." Replicators (such as DNA, or genes) team up in vehicles that gather resources for them, but the actual entity that's evolving is the replicator, not the vehicle.

For Dawkins, "organism" and "group of organisms" are candidates for the "vehicle" role, but neither are candidates for the "replicator" role. Between individuals and groups, "individuals" win out as vehicles, because the category "group" is too "wishy-washy." The unity of an individual lion far surpasses the unity of a pride of lions.

Dawkins thinks that by definition, evolution can only get off the ground when there's a replicating entity. Organisms and species aren't replicators, but "vehicles," so the group selectionists are wrong to think that species and not genes evolve.

The Extended Phenotype attempts to answer questions about why genes gang up in cells, live in **survival machines**, and transfer to new hosts via a "bottleneck" route of reproduction. Dawkins briefly sketches out some of those answers here.

Dawkins thinks the idea of a discrete individual is an illusion created by genes that benefit from teaming up into cells and bodies and making bodies reproduce.

Cells, to Dawkins, are like pharmaceutical factories. DNA molecules make proteins that work as enzymes (they cause chemical reactions). Each gene makes one type of enzyme. But sometimes multiple enzymes are needed to make a useful product. So, a cell is like a production line that makes an end-product through a series of intermediate steps. Cells essentially keep the genes that cooperate together. However, the cooperating genes aren't selected as a "group." They come together by chance, and if their combination doesn't produce a viable end product, the cell dies. At the bottom of all this behavior is still a single selfish gene that benefits from cooperation with other genes.

It's tempting to think of a cell as a unified entity. But Dawkins thinks that really, cells are more like a "production line" in which multiple genes work together to create a product: a protein wall. If the genes don't work well together, the end-product is mangled, the protein wall can't be built, and the genes (little chunks of DNA) can't protect their molecules from being stolen by other replicators. Even at the cellular level, cooperation only happens among genes if there is a selfish payoff to a single gene.

Dawkins wonders next why cells clump together into bodies or "lumbering robots." He remembers that each cell is a clone containing all the genes in the whole body. He decides that cells that club together can "specialize." Some of them can focus on watching for predators, others can focus on digesting food, and so on. This means that different genes are "turned on" in different cells. The genes that are turned on in one cell benefit their copies that are dormant in other cells.

Dawkins thinks the only reason that bodies exist at all is because it's more efficient for genes to divide and conquer the work of making a survival machine effective, which benefits all their clone-genes in all the other cells in that survival machines. The teamwork creates the illusion of a single body, but really, the body is just a group of self-interested genes cooperating for mutual benefits.

Finally, Dawkins wonders why genes propagate through the "bottleneck" route of reproduction. It doesn't matter how big or complex an organism is— each time, the next generation begins with a new single cell, a fertilized egg. He thinks this is like "going back to the drawing board." Genes don't take an existing heart and remodel it into a new one—they grow new ones "inspired" by the previous model. The "growth cycle" of an embryo (including birth and childhood) also allows certain genes to be turned on at certain points in the growth cycle. Dawkins thinks this is necessary for precise and complex organs like bird's wings or eagle's eyes to be created. He calls this an "orderly timing cycle."

It seems like bodies are individuals that create other individuals through reproduction, which all together compile a discrete group. But Dawkins thinks the real reason genes make the world look like this is because building new embryos enables genes to cooperate and build more complex survival machines based on when each gene is activated as the embryo grows. Reproduction, too, is just an example of genes cooperating for the mutual benefit of their own survival.

The third reason for a bottleneck life cycle is "cellular uniformity." Evolution happens through cell mutation. Imagine there's a plant called "splurge-weed" that reproduces by shedding a branch that grows another body. A mutant gene would have to spread one by one into all the cells of the splurge weed before the next shedding happened. But if a mutant gene arises in a single cell that clones itself to make a new body (say, in another imaginary plant called "bottle-wrack") it's already automatically going to be in every cell of the embryo that's built. It's also more likely the cells in that **survival machine** will cooperate, since they have the same interest at heart: propagation of the genes inside them. Dawkins thinks the evolutionary payoff of a "bottleneck" reproductive cycle is why there are discrete organisms at all.

Dawkins gives another reason for why reproduction happens, to show that it's got nothing to do with making individuals. In fact, it just makes replication more efficient. A gene that mutates before an embryo is created automatically spreads to all the cells in that embryo. That's much more efficient than a gene that mutates in one cell and then trying to spread to each other cell one by one. Reproduction, in other words, is the most efficient way for a gene to replicate. Dawkins stresses once again that organisms only exist because of genes attempting to propagate themselves.

There's a lot more to *The Extended Phenotype*, but Dawkins hopes he's given a "flavor" of the book here. He concludes by giving a "brief manifesto" of the "selfish gene/extended phenotype" view of life, which he thinks applies to all living beings, everywhere in the universe. The manifesto begins with the claim that "fundamental unit—the "prime mover of all life"—is the replicator. A replicator is "anything in the universe of which copies are made." Replicators come into existence by chance, but once they exist, they can make infinite copies of themselves.

Dawkins takes stock of what he has said so far, to make a larger "manifesto" about evolution in general. He thinks it's impossible for evolution to happen at all without something that becomes more numerous by making copies of itself (replicating). A replicator can be anything so long as it makes copies or clones of itself: DNA, ideas, maybe even electronic circuits, or silicone. The evolving unit in every context is always the replicator.

Since no copying process is perfect, slightly different replicators will emerge that are better or worse at making copies of themselves. The ones that are best at making copies of themselves "come to dominate the population." Over time, "the world becomes filled with the most powerful and ingenious replicators."

The reason why evolution happens at all is because replicators sometimes make imperfect copies of themselves, which compete with the original replicators over finite resources. Saying that evolution happens is tantamount to saying that replicators compete, and the best ones win.

Replicators will find more and more elaborate ways of perpetuating themselves. Replicators survive because of their "consequences on the world." These can be quite indirect, but as long as they affect the replicator's success at getting copied, they still count. The success of a replicator depends on the world it's placed in. One of the most important factors is other replicators. Just like the **oarsmen**, replicators that work well together to achieve a joint goal will dominate the world.

The success of a replicator depends on how it gets resources in the world in which it emerges. In many cases, replicators are able to make more copies of themselves when they team up and cooperate. The oarsmen analogy shows that eight oarsmen rowing together are far more likely to win a race than one oarsman rowing by himself.

At some point in time, this "ganging up of mutually compatible replicators" formalized into discrete vehicles: "cells, and later, many celled bodies." The vehicles that evolved a "bottleneck" life cycle prospered. This made them more "discrete" and "vehicle-like." This "packaging of living material into discrete vehicles" became so visible that, when biologists started inquiring about the world around them, "their questions were mostly about vehicles—individual organisms." Dawkins thinks that biology needs to be turned "the right way up" by realizing that replicators came first. He suggests that one way to do this is to remember that phenotypic effects of a gene are not limited to the body it lives in.

When replicators in the natural world (DNA) team up, or cooperate for better success, they happen to create vehicles (first cells, then bodies, and eventually bodies that reproduce). And when evolutionary biologists started to think about evolution, they saw individual bodies functioning in a world and assumed evolution started there. Dawkins thinks they missed an essential part of the picture: without replicators, there would be no bodies. Bodies are just some of the phenotypic effects of genes (replicators), but there are many more, extending far into the world.

If one use one's imagination, one can see the gene as "sitting at the centre of a radiating web of extended phenotypic power." Similarly, one can imagine every object in the world sitting at the center of several converging webs of influences from many genes sitting in many organisms. The world is "criss-crossed" with arrows joining phenotypic effects to genes. Dawkins concludes that replicators are no longer peppered freely around the universe. They are packaged into individual bodies. Similarly, many phenotypic effects have "congealed" into those bodies instead of being spread evenly throughout the world. But the "individual body" did not have to exist. The only kind of entity that has to exist for life to arise is the immortal replicator.

Dawkins suggests that the reader might be able to shift into a mindset of thinking about replicators and phenotypic effects by thinking about a gene as the center of a "web." Its phenotypic effects extend, like a spider's web, out into the world, and cross over many other webs. Individuals are really just dense areas where there are many tightly "criss-crossed" or "congealed" webs. There are so many crossovers that the webs almost look like a solid object. What's really at stake, however, isn't the congealed web, but the replicator creating that web.

EPILOGUE TO 40TH ANNIVERSARY EDITION

Genetic research has come so far since Dawkins wrote *The Selfish Gene* that one might think he would need to revise the whole book. But he's convinced that he doesn't need to do that, because of the special way he's defining "gene." He uses the definition of "gene" created by Williams (also used by Maynard Smith and Hamilton). Williams defines the gene as "any portion of chromosomal material that potentially lasts for enough generations to serve as a unit of natural selection." Dawkins jokes that technically, a more accurate title for this book would be "the slightly selfish little bit of chromosome and the even more selfish little bit of chromosome."

Dawkins wants to convince the reader that even though scientists now know a lot more about genes than they did when he wrote this book, his argument is still valid. That's because geneticists are concerned with what a gene is made of, whereas he's concerned with how genes function. Dawkins offering a functionalist account: it focuses on what a gene does, *not what it's made of. It's still true that genes replicate themselves, which triggers evolution, regardless of what the genes happen to be made of.*

Embryologists are concerned with how genes affect phenotypes based on what they're made of. However, like Darwin, Dawkins is only concerned with how something become numerous in a population. He reiterates that this "something" can't be organisms, because they don't become numerous: each organism is unique. The phenotypic effects of genes determine how numerous they become. Successful genes exist in many bodies over time. Genes help bodies survive "long enough to reproduce in the environment." "Environment" includes things that are outside the body (such as predators and the weather), but also things that are inside the body (especially other genes).

Similar to geneticists, embryologists look at how what a gene is made of changes the phenotypic effects that it has. But Dawkins is only concerned with the fact that genes create phenotypic effects (whatever they are) in order replicate. Organisms don't replicate because they don't copy or clone themselves, so they don't evolve—their genes do. Once again, Dawkins stresses that phenotypic effects extend beyond single organisms into the environment and into other organisms, but this all happens so that the gene can replicate.

It makes sense that natural selection favors genes that "flourish in the company of other genes in the population." Genes are "selfish," but they are also "cooperative" with genes in the same body and in other bodies. Organisms that reproduce sexually are effectively "a cartel of mutually compatible cooperating genes." These genes don't cooperate because they're selected as a group. Rather, they're selected individually, and they tend to survive if they also happen to cooperate. Dawkins could easily call his book *The Cooperating Gene* and the content wouldn't change.

As Dawkins has stressed multiple times in his argument, everything observable in the world happens because genes are replicating. Cooperation among genes is so common that he could have easily called his book The Cooperating Gene. *In either case his core point still stands: cooperation only happens because it helps individual genes replicate.*

Dawkins could have also called his book *The Immortal Gene* and the content would still be the same. He speculates that "immortal" might have been a better word, because it captures an important claim in his argument. Evolution is possible because of the "high fidelity" of DNA copying. DNA molecules mostly copy themselves accurately. This means that successful genes can live on for millions of years in the form of exact copies of themselves. Bill Hamilton calculated genetic relatedness by thinking about how much more related one is to kin than to the base population, which is another claim that Dawkins endorses.

Dawkins reminds the reader that successful genes perpetuate themselves in the long-term picture of evolution. Every gene that exists now came from the same source: it was a miscopy of a replicator. All the human genes in the world are related in a sense, since they evolved from the same ancestor genes. In a sense, we're all related. It really doesn't make sense to draw a hard line between kin and strangers, as group selectionists do. The only thing that matters is the number of genes two survival machines have in common.

Dawkins says that "genes" (as Williams defines them) are "things you can count as the generations go by." He means that *The Selfish Gene* is probably "a valid account of life on other planets even if the genes on those other planets have no connection with DNA."

Dawkins stresses that evolution is a process. This process could arise anywhere in the universe, among any kind of entity that becomes more numerous as time passes. If one replaces the word "gene" in his account with the name of a different replicator, the same argument—about how evolution happens—would hold.

Dawkins wonders how related he is to Queen Elizabeth II. Apparently, he's her "15th cousin twice removed." His point is that humans are all "cousins" to each other, in some way or another, by virtue of our shared ancestors. We're part of the "background population" in which our relatedness is nearly (but not quite) zero. Dawkins finds calculating exactly what level of cousin one is to someone else to be kind of pointless. It makes more sense to think about how related people are from the "point of view of the gene." For example, "what relation is my blue eyed gene to the postman's blue eyed gene?"

Dawkins reiterates that all humans are very distant relatives of each other, since our genes originated from ancestor genes that we have in common. He thinks that group selectionists are barking up the wrong tree when they try to figure out how closely related an individual is to others, and what effect that will have on the group overall. Once again, the only thing that matters is the genes that individuals have in common.

Unlike organisms (which tend to have two parents, four grandparents, and so on), genes only have one parent. That means any two people can trace every one of their genes back to a common ancestor. The "coalescence point" is the point at which one person's gene and the other person's gene "peeled off" from their common ancestor. Dawkins thinks "the gene's eye view" of evolution can extend into much deeper territory than "altruism."

Dawkins has focused on showing that the "gene's eye view" of evolution makes much better sense of altruism than group selectionists do. He also thinks the "gene's eye view" of evolution is better because looking at the ancestry of genes might explain a whole lot more about life on Earth than looking at evolution on a species level will.

Dawkins believes that one can derive information about the entire "prehistory" of an entire species from genes. He tried this on a television show once by having the genes in one of his cells decoded. He discovered that a lot of genes coalesced 60,000 years ago, but a few coalesced 300,000 years ago. This means that the population was larger 300,000 years ago than 60,000 years ago. Likely, there was some sort of catastrophe between the two dates that drastically shrunk the population. The "gene's eye view of life" thus "illuminates the deep past." Dawkins discusses this idea more in *The Ancestor's Tale* (co-authored with Yan Wong).

Dawkins describes how sequencing his own genome for a television show disclosed important facts about the human population hundreds of thousands of years ago. He does this to illustrate how important genes are for understanding the early history of life on earth. Once again, he implies that looking at genes is a lot more informative about the history of life on Earth than looking at species is.

According to Dawkins, "the gene pool of a species is a mutually supportive cartel of genes that have survived in particular environments of the past, both distant and recent." A geneticist could learn about all the environments in which a gene survived from its genetic code. Dawkins speculates that one can learn about ancient deserts from the genes of camels and one can learn about ancient oceans from the genes of dolphins.

Dawkins argues that looking at genes can also help scientists map the earth's landscape in ancient historical periods, in order to convince the reader that the "gene's eye view of evolution" has more explanatory power than the group selection view of evolution.

Genomes even contain information about prehistorical eras, such as times when dinosaurs were alive, and even earlier when humans' ancestors were fish. Dawkins would like to write a book about this someday, called "The Genetic Book of the Dead." He thinks such a project would provide him with fresh insights to add, when future editions of *The Selfish Gene* are released.

Finally, Dawkins speculates about the vast potential of genes even beyond what the reader might have imagined so far. Perhaps he'll inspire some new research. At the very least he hopes the reader is convinced that genes really are the key to understanding life's origins on Earth.

HOW TO CITE

To cite this LitChart:

MLA

Naqvi, Erum. "*The Selfish Gene.*" *LitCharts*. LitCharts LLC, 28 Nov 2019. Web. 21 Apr 2020.

CHICAGO MANUAL

Naqvi, Erum. "*The Selfish Gene.*" LitCharts LLC, November 28, 2019. Retrieved April 21, 2020. https://www.litcharts.com/lit/the-selfish-gene.

To cite any of the quotes from *The Selfish Gene* covered in the Quotes section of this LitChart:

MLA

Dawkins, Richard. The Selfish Gene. Oxford University Press. 2016.

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Dawkins, Richard. The Selfish Gene. Oxford: Oxford University Press. 2016.