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The THIRD CULTURE

by John Brockman

A TOUCHSTONE BOOK
Published by Simon & Schuster

Chapter 3

RICHARD DAWKINS

"A Survival Machine"

W. DANIEL HILLIS: Notions like selfish genes, memes, and extended phenotypes are powerful and exciting. They make me think differently. Unfortunately, I spend a lot of time arguing against people who have overinterpreted these ideas. They're too easily misunderstood as explaining more than they do. So you see, this Dawkins is a dangerous guy. Like Marx. Or Darwin.

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RICHARD DAWKINS is an evolutionary biologist; reader in the Department of Zoology at Oxford University; Fellow of New College; author of The Selfish Gene *(1976, 2d ed. 1989),* The Extended Phenotype *(1982),* The Blind Watchmaker *(1986), and* River out of Eden *(1995).*

RICHARD DAWKINS: Some time ago, I had a strangely moving experience. I was being interviewed by a Japanese television company, which had hired an English actor and dressed him up as Darwin. During the filming, I opened a door and greeted "Darwin." He and I then entered into a discussion out of time. I presented modern neo-Darwinist ideas and "Darwin" acted astounded, delighted, and surprised. There are indeed indications that Darwin would have been pleased about this modern way of looking at his ideas, because we know he was very troubled by genetics all his life. In Darwin's time, nobody understood genetics, except Mendel, but Darwin never read Mendel; practically nobody read Mendel.

If only Darwin had read Mendel! A gigantic piece of the jigsaw would have clicked into place. Darwin was troubled by the problem of blending inheritance. In his time, it was thought that we were all a kind of mixture of our parents, in the same way you mix black and white paint and get gray paint. It was pointed out that if that was true, as indeed everybody thought it was, then natural selection couldn't work, because the variation would run out. We would all become just a kind of uniform gray.

Darwin struggled and struggled to get around that. Anybody could see that it wasn't true. We didn't become a uniform shade of gray. Grandchildren aren't more uniform in their generation than their grandparents' generation. Mendelian genetics, and the population genetics of the 1930s, was the vital piece that Darwin needed. Darwin would have been delighted and astounded by population genetics, the neo-Darwinism of the 1930s. It's also nice to think that he might have been pleased about kin selection and selfish genes as well.

I approach evolution by taking a "gene's-eye view," not because I'm a geneticist or particularly interested in genetics, but because when I was trying to teach Darwinism, particularly the evolution of animal behavior, I came up against social behavior, parental behavior, mating behavior, which often look as though they are cooperative. It rapidly became clear to me that the most imaginative way of looking at evolution, and the most inspiring way of teaching it, was to say that it's all about the genes. It's the genes that, for their own good, are manipulating the bodies they ride about in. The individual organism is a survival machine for its genes.

I began to develop this rhetoric in 1966, when I was just postdoctoral, and the ethologist Niko Tinbergen asked me to do a course of lectures at Oxford. At that time, W.D. Hamilton's theory of kin selection had just been published, which inspired me. I generalized Hamilton's way of thinking to the whole of social behavior, teaching my students to think about animals as machines carrying their instructions around. The focus of the enterprise was that the individual organisms were tools, levers. Their limbs, fingers, feet were levers of power to propel the genes into the next generation.

I wrote *The Selfish Gene* about ten years later, and that was what I became known for. Many people thought of it as a new idea, which it wasn't. I simply thought that way of looking at things was an imaginative, vivid way of presenting standard Darwinism. It was a new and different way of seeing it.

The idea of the selfish gene is not mine, but I've done the most to sell it, and I've developed the rhetoric of it. The notion is implicit in the approach of the turn-of-the-century biologist August Weismann and in the neo-Darwinian synthesis of the 1930s. The idea was carried forward in the 1960s by W.D. Hamilton (then in London, now my colleague at Oxford) and by George C. Williams, at Stony Brook. My contribution to the idea of the selfish gene was to put rhetoric into it and spell out its implications.

The selfish-gene idea is the idea that the animal is a survival machine for its genes. The animal is a robot that has a brain, eyes, hands, and so on, but it also carries around its own blueprint, its own instructions. This is important, because if the animal gets eaten, if it dies, then the blueprint dies as well. The only genes that get through the generations are the ones that have managed to make their robots avoid getting eaten and succeed in living long enough to reproduce.

Another way of putting it is to say that the world is full of genes that have come down through an unbroken line of successful ancestors, because if they were unsuccessful they wouldn't be ancestors and the genes wouldn't still be here. Every one of our genes has sat successively in our parents, our grandparents, our great-grandparents—every single generation. Every one of our genes, except new mutations, has made it, has been in a successful body. There have been lots of unsuccessful bodies that have never made it, and none of their genes are still with us. The world is full of successful genes, and success means building good survival machines.

The reductionist aspect of the gene-centered view of natural selection makes some people uncomfortable. Reductionism has become a dirty word in certain circles. There's a kind of reductionism which is obviously silly and which no sensible person adopts, and that's what Dan Dennett calls "greedy reductionism." My own version of it is "precipice reductionism." If you take something like a computer: we know that everything a computer does is in principle explicable in terms of electrons moving along wires, or moving along semiconductor pathways. Nobody but a lunatic would attempt to explain what is going on in terms of electrons when you use Microsoft *Word*. To do so would be greedy reductionism. The equivalent of that would be to try to explain Shakespeare's poetry in terms of nerve impulses. You explain things in a hierarchy of levels. In the case of the computer, you explain the top-level software—something like Microsoft *Word*—in terms of software one level down, which would be procedures, subprograms, subroutines, and then you explain how they work in terms of another level down. We would go through the levels of machine codes, and we would then go down from machine codes to the level of semiconductor chips, and then you go down and explain them in terms of physics. This orderly, step-by-step way—what I call step-by-step reductionism, or hierarchical reductionism—is the proper way for science to proceed.

Reductionism is explanation. Everything must be explained reductionistically. But it must be explained hierarchically and in step-by-step reductionism. Greedy reductionism, or precipice reductionism, is to leap from the top of the hierarchy down to the bottom of the hierarchy in one step. That you can't do; you won't explain anything to anybody's satisfaction.

It's a fair point that the gene is an abstraction. At one level, a gene is a bit of DNA. The Caltech biologist Seymour Benzer classified the gene—divided the gene up—and said that we've got to stop talking about "*the* gene." He divided it into the "recon," the unit of recombination; the "muton," the unit of mutation; and the "cistron," which he defined in a particular way, but it approximately amounts to the length of DNA that codes for one polypeptide chain.

So a critic might ask, "Which gene are you talking about?" when you are talking about the gene as a unit of selection. What I've said in *The Selfish Gene* is that I agree that we're not talking about a particular unit. There's a continuum. The only reason why it's important that it's the gene that's the unit of selection is that the gene is what goes on forever. The gene is what goes on for a very large number of generations. Those units of communication that go on through many generations are the successful ones. They're successful by virtue of their effects upon phenotypes. The unit of selection doesn't have to be the cistron. It can be the length of any number of cistrons—technically not one gene, but it would be one gene for my purposes if, say, once it gets together as a cluster it tends to go on for a large number of generations and is therefore available for natural selection to work on.

My key effort would be, if anything, the extended phenotype. The gene is the unit of selection, in that it exerts phenotypic effects. Genes that are successful are the ones that have effects upon bodies. They make bodies have sharp claws for catching prey, for example. If you follow through the logic of what's going on, there's a causal arrow leading from a gene change to a phenotype change. A gene changes, and as a consequence there's a cascade of effects running through embryology. At the end of that cascade of effects, the claws become sharper, and because the claws become sharper, that individual catches more prey. Therefore the genes that made the claws sharper end up in the bodies of more offspring. That's standard Darwinism.

The extended phenotype allows that cascade of causal arrows to reach out beyond the body wall. Extended phenotypes are things like birds' nests, or bower-bird bowers. A peacock has a tail with which it woos females. A male bower bird builds a grass tail, a bower, in the bushes, and dances around it, and that's what attracts the females. That bower made of grass is performing exactly the same role as a peacock's tail. Genes that make for a good bower, a pretty bower, get

passed on to the next generation. The bower is a phenotypic effect of genes. It's an extended phenotype.

There are genes for bowers of different shapes. A caddis worm builds a house made of stones. Some might build a house made of sticks, others might build one of dead leaves. This is undoubtedly a Darwinian adaptation. Therefore there must be genes for stone shape, stone color, all the properties of the house; to the extent that they're Darwinian adaptations, they must be genetic effects. These are just examples to illustrate the point that the cascade of causal arrows leading from genes to phenotypes doesn't have to stop at the body wall. It goes beyond the body wall until it hits things like stones, grass.

The extended phenotype is completely logical. It means that anything out there in the world could be a phenotypic effect of my genes. In practice, most of them aren't, but there's no reason in principle why they shouldn't be. Something like a beaver dam causes a flood, which creates a lake, which is to the benefit of the beaver. That lake is an adaptation for the beaver. It's an extended phenotype. There are genes for big lakes, deep lakes: lake phenotypes have genetic causes. You can build up to a vision of causal arrows leading from genes and reaching out and affecting the world at large.

Our genes are like a colony of viruses—socialized viruses, as opposed to anarchic viruses. They're socialized in the sense that they all work together to produce the body and make the body do what's good for all of them. The only reason they do that is that they all are destined to leave the present body and enter the next generation by the same route, sperms or eggs. If they could break out of that route and get to the next generation by being sneezed out and breathed in by the next victim, that's what they would do.

Those are what we call anarchic viruses. Anarchic viruses, the ones that make us sneeze, are the ones that don't agree with each other. They don't care if we die. All they want to do is make us sneeze, or, in the case of the rabies virus, make the dog salivate and bite. But most of our genes are socialized viruses, socialized replicators. They're disciplined and cooperative precisely because they have only one way out of the present body: by sperm or egg.

Before the gene-centered view of natural selection became fashionable, people used to say that if something was good it would happen. This has led some to believe that the adaptationist approach is an easy game. It's been said that you can easily come up with some Darwinian idea to explain anything. As against that, the proper understanding of Darwinism at the gene level severely limits you to a certain kind of explanation. It's not good enough just to say that if something is vaguely advantageous it will evolve. You have to say that it's good for the genes that made it. That automatically wipes out great swathes of possible facile explanations.

Computers are by far the best metaphor for lots of things, because they're so immensely complicated. They resemble living things in so many respects. The whole idea of programming the behavior of a mechanism in advance is vital to the understanding of living organisms. From the selfish-gene point of view, we are robot survival machines, and because genes themselves can't pick things up, catch things, eat things, or run around, they have to do that by proxy; they have to build machines to do it for them. That is us. These machines are programmed in advance.

I've used metaphors like the idea of alien beings from outer space who wish to travel to a distant galaxy and can't, because they can't travel that fast, so what they do is beam instructions at the speed of light, and those instructions make people on some distant planet build a computer, in which the instructions can be run. Instructions are all you need in order to re-create the life-form. It's controlling its programming in advance, given that you cannot program the day-to-day running of the thing. The distant galaxy is too far away: you can't send orders, can't say, "Now do this, now do that," because every instruction takes millions of years to get there. You send a program that anticipates all possible eventualities so that it doesn't need to have instructions sent to it; the instructions are all there. That's what the genes are. Success in evolution is building programs that don't crash. Programs that crash don't perpetuate themselves. The best way to look at an individual animal is as a robot survival machine carrying around its own building program.

I developed the idea of the "cultural meme" as a way of dramatizing the fact that genes aren't everything in the world of Darwinism. The fact that scientists in varied fields have picked up on the metaphor suggests that the idea is itself a good meme. The meme, the unit of cultural inheritance, ties into the idea of the replicator as the fundamental unit of Darwinism. The replicator can be anything

that replicates itself and exerts some power over the world to increase or decrease its probability of being replicated. DNA happens to do that remarkably well, but DNA isn't the only thing that in principle could do that. Life on other planets is not going to have DNA but is certainly going to have some kind of replicator. The meme is another example of something that might be doing Darwinism, here on Earth. Maybe we don't have to go to other planets to see another kind of Darwinism going on. Maybe we've got it staring us in the face here, in the form of cultural replicators.

If I represent the ultra-Darwinist view, Brian Goodwin has a much different approach. He thinks he's anti-Darwinian, although he can't be, because he has no alternative explanation. He's primarily interested in embryology—in how you make what is—whereas I'm interested in how what is evolves. He thinks that what's interesting about living forms is almost a special kind of physics. He uses the analogy of a whirlpool, which has a nice spiral shape to it, and the spiral shape comes from the laws of physics. But the laws of physics allow two stable states: either a clockwise spiral or an anticlockwise spiral.

For Goodwin, what genes can do is, in effect, switch the spiral from clockwise to anticlockwise, but they can't do anything else. Everything that's elegant and beautiful about the spiral comes from the laws of physics. He thinks that that's what genes are doing in us—which is easy to believe in something like a snail shell or a ram's horn, because they look like a whirlpool, but Goodwin thinks that's true of everything. He thinks that physics is responsible for the business part of life, and all that genes do is make a choice between the various stable states allowed by physics.

For Goodwin, evolution is just kind of picking its way from one stable state to another. That could be right; it's not contrary to my view, except in detail. There's a continuum between a kind of extreme Goodwin view and my extreme view. I believe that there's not a lot that genes can't achieve in the way of small-scale, gradual, step-by-step change from what's already there. If you are a rhino with a big horn, and if natural selection wanted to change it to a short horn, a sharper horn, a blunter horn, a fatter one, a thinner one—that, to me, is child's play. I'm sure it could be done, whereas Goodwin might feel that only certain shapes of horn are permissible. That's an open question. There could well be serious limitations in what embryology allows. I'm not hostile to that idea; it isn't anti-Darwinian.

The best olive branch I can offer to Goodwin and his colleagues is what I call "kaleidoscopic embryology." Think about a kaleidoscope: you have a little heap of colored chips inside a tube, and the chips are clustered at random, but then you look at them through a series of mirrors, which makes them appear as a beautiful, symmetrical pattern, which may resemble a flower, say. When you tap the side of the kaleidoscope, all that really happens is that the colored chips slip down a bit and change their position, but what you see on the screen is the symmetrical pattern change in elegant ways. Embryologies are kaleidoscopic, in the sense that mutations may produce complicated effects. Embryology itself is a complicated process, such that a random change, a mutation, manifests itself like the image that results when you tap a kaleidoscope. In some cases, the complication is literally a matter of symmetry, if you think about something like a starfish, which has five arms, all the same as each other. Different starfish clearly evolve by ordinary mutational processes. But a mutation that, let's say, changes the shape of all five arms at the same time works in five places at once. Similarly, an earthworm is a long structure with lots of segments that are essentially the same, or a millipede is a long structure with lots of segments. A mutation that makes the legs longer or shorter or blacker or browner works on all the legs at once. Those are two examples of kaleidoscopic embryology. Mutation is filtered through the existing processes of embryology, and the consequences of mutation are complicated. That's what I mean by kaleidoscopic embryology.

Natural selection in the short term favors those mutations that survive, obviously. But there may be a kind of higher-order selection in favor of embryologies that are kaleidoscopic in productive ways. Things like the five-way symmetry of starfish and sea urchins—the embryologies they have may be especially good at evolving. It may be that as evolutionary time goes on, you get not only selection in the short term, in favor of individuals who are good at surviving and reproducing, but every now and again there's a major change in the embryology, which makes it kaleidoscopic in a different way, and which is then favored by a higher-order selection, because certain new embryologies are good at evolving. Perhaps particularly when a continent is cleaned out by a mass extinction and there's a vacuum waiting to be filled, it may be that it will be filled by whatever group

of animals has an embryology good at rapidly radiating and evolving into a whole range of new lineages.

Extinctions happen and are enormously important in evolutionary history. There's no doubt that if the dinosaurs had not gone extinct the entire history of life would be different. There probably wouldn't be mammals, for example. Very probably the dinosaurs went extinct sixty-five million years ago for a reason that had absolutely nothing to do with natural selection but because of some catastrophe. That's happened several times in the history of life, and provides the environmental framework in which natural selection works. But only natural selection, short-term selection of short-term advantage, gradualistic change, is responsible for the buildup of complex adaptation. Extinction cleans the slate, allows a new kind of life-form—mammals, in this particular case—to thrive.

My view of this is encapsulated in my phrase "the evolution of evolvability." Certain embryologies may be better at evolving than others. There may be a kind of higher-order selection for life-forms that are not only good at surviving, which is ordinary Darwinism, but are good at evolving. Each time there's an extinction, a new life-form starts to spread and to evolve—in a real sense, to inherit the earth. After the dinosaurs went extinct, the mammals inherited the earth. There may have been something about mammalian embryology which made the mammal body plan good at suddenly evolving, taking advantage of a slate that had been wiped clean. If you wipe a slate clean, there's going to be a mad rush of forms to start evolving to fill all the various traits: carnivore, herbivore, big carnivore, big herbivore, little carnivore, little herbivore, and so on. There may be some embryologies that just aren't very good at radiating out to fill all those vacant slots. There may be others that are very plastic, very good at evolving, very good at taking advantage of changes in the climate and evolving in a widely radiating way.

On the face of it, this idea is rather different from the view I'm associated with. I came to it through playing with my computer biomorphs—the blind-watchmaker computer program. I learned from this program that certain computer algorithms are better at evolving in the biomorphic, blind-watchmaker kind of program than others. I could then imagine a higher-order selection in favor of being good at evolving.

Stephen Jay Gould argues against progress in evolution. We all agree that there's no progress. If we ask ourselves why some major groups go extinct and others don't, why the Burgess Shale fauna no longer exist, I'm sure the answer is "Bad luck." Whoever thought otherwise? There's nothing new about that. On the other hand, the short-term evolution within a group towards improved adaptation—predators having arms races against prey, parasites having arms races against hosts—that *is* progressive, but only for a short time. It's not that everything in evolution has to be progressive, but there will be a period of a million years when a lineage of prey animals is evolving together with a lineage of predator animals, and they're all getting faster and faster, their sense organs are evolving, their eyes are getting sharper, their claws are getting sharper: that's progressive. The prey animals are getting better because their predators are getting better.

I agree that there's no sense in which evolution was ever aiming towards a distant goal of humanity. That would be ludicrous. No serious evolutionist ever thought that. Gould seems to be saying things that are more radical than they really are. He pretends. He sets up windmills to tilt at which aren't serious targets at all.

The "pluralist" view of evolution is a misunderstanding of the distinction I make between replicators and vehicles. Natural selection works at the level of replicators, in the sense that the world becomes filled with successful replicators and empty of unsuccessful replicators. The way those replicators are successful or unsuccessful is by being good at building vehicles, or phenotypic effects. Those vehicles form themselves into a hierarchy of individuals, groups, species, and so on. The differential success of vehicles can be talked about at all levels of that hierarchy. There's a hierarchy in levels of selection as long as you are talking about vehicles. But if you're talking about replicators, there isn't. There's only one replicator we know of, unless you count memes.

Steve doesn't understand this. He keeps going on about hierarchies as though the gene is the bottom level in the hierarchy. The gene has nothing to do with the bottom level in the hierarchy. It's out to one side.

Gould and I aren't just popularizers. Our ideas actually influence and change people's lives—change the way other scientists think, make them think in a different, constructive way. There's a tendency

to downplay popularizing. I would not want to use the word "popularizer" for either of us. It's hard to draw a line between the creative and the popularizing. I like to think of myself as a creative force in the field. This differs from reporting—writing a book that explains the existing orthodoxy so that people can understand it. We don't do that. We do something creative: we change people's minds.

On the other hand, when you say we're the two leading evolutionary thinkers, that's not true. The big creative names in evolution today are W.D. Hamilton, John Maynard Smith, and George Williams. Hamilton is the inventor of kin selection. He's now concentrating on sex, because sex is a big problem in evolution theory. What's it for; why is it there? He's provided the latest and probably the most promising theory of what sex is about. He thinks that the reason for sex is as an adaptation against parasites. It's a very exciting, revolutionary way of viewing evolution: evolution as a dynamic, continuous, running-as-hard-as-you-can-to-stay-in-one-place vision. All his career, Hamilton has been original, stimulating, and has inspired generations of research workers to new efforts.

I'm considered by some to be a zealot. This comes partly from a passionate revulsion against fatuous religious prejudices, which I think lead to evil. As far as being a scientist is concerned, my zealotry comes from a deep concern for the truth. I'm extremely hostile towards any sort of obscurantism, pretension. If I think somebody's a fake, if somebody isn't genuinely concerned about what actually is true but is instead doing something for some other motive, if somebody is trying to appear like an intellectual, or trying to appear more profound than he is, or more mysterious than he is, I'm very hostile to that. There's a certain amount of that in religion. The universe is a difficult enough place to understand already without introducing additional mystical mysteriousness that's not actually there. Another point is esthetic: the universe is genuinely mysterious, grand, beautiful, awe inspiring. The kinds of views of the universe which religious people have traditionally embraced have been puny, pathetic, and measly in comparison to the way the universe actually is. The universe presented by organized religions is a poky little medieval universe, and extremely limited.

I'm a Darwinist because I believe the only alternatives are Lamarckism or God, neither of which does the job as an explanatory principle. Life in the universe is either Darwinian or something else not yet thought of.

There's only one general principle in biology, and that, of course, is Darwinism. Nobody doubts the importance of evolutionary theory; nobody doubts that Darwinian evolution is the central theory of biology. But there's a hell of a lot to do in the way of convincing people at large. As you know, 50 percent of the American population don't even believe in evolution, let alone Darwinism. The attacks upon Darwinism, coming as they do from a position of ignorance, tend to build up a reaction. It's undoubtedly true that evolution has happened; to deny that is rather like denying that the world is round. Therefore it's possible for evolutionary biologists to come across as arrogant. Physicists don't have to deal with this.

I'm becoming increasingly interested in computer models and artificial life, because I'm interested in Darwinism as a general phenomenon: what will Darwinism have to be like, in principle, anywhere in the universe. We can't travel to other places where there's life. I believe there probably is life elsewhere in the universe, but we're not sure and we'll almost certainly never know. There are lots of Darwinisms around the universe, but we've got only one to study. We've got lots of animals to study, lots of plants to study, lots of groups of animals and plants to study, but only one Darwinism.

The next best thing to going to another planet is to set up an artificial world, and the computer is the obvious place to set it up in. In the silicon world of a computer, you can pack in such a lot, and there's room for things to go on in that world. You can make your model world have any property you like, and then try to set your Darwinism going in that model world, and with a bit of luck determine which of the essential aspects of this planet's Darwin-ism are essential in the model world and which are incidental, and vice versa.

GEORGE C. WILLIAMS: Although I've criticized it, Dawkins' replicator concept, presented in *The Selfish Gene*, was certainly an important conceptual advance. I have nothing but respect and admiration for Dawkins.

LYNN MARGULIS: Richard Dawkins epitomizes my comments about how scientists rationalize. In his televised response to the Gaia hypothesis, he said, and I quote: "The idea [of Gaia] is not dangerous or distressing except to academic scientists who value the truth." That quote captures the arrogance of Dawkins. I invited him to come and discuss Gaia ideas with Lovelock and me, and he declined even a telephone conversation. I would have happily arranged such a trip and a meaningful idea-tournament with Jim, as Dawkins knew. He prefers to take potshots instead of actually discussing the details of Gaia. When he says Gaia is "dangerous and distressing to scientists who value the truth," he's talking about himself. Gaia is dangerous and distressing to him because, unlike the rest of us, *he* values the truth. The inference of his statement simply exposes his solipsism.

MARVIN MINSKY: I adore Richard Dawkins' conception of memes—that is, structured units of knowledge that are able, more or less, to reproduce themselves by making copies of themselves from one mind to another. A few million years ago, some of our ancestors evolved some brain machinery that was specialized for representing knowledge in a serial and "explicit" fashion, rather than in a parallel and "implicit" manner. These early primate ancestors of ours began to be able to transmit the fruits of their experience by vocal signals—and eventually that led to rapid advances both in already existing abilities to learn and represent knowledge and, perhaps more important, in the social evolution of new ideas. By improving each brain's ability to do serial processing, the entire society was enabled to accumulate knowledge in parallel. Consequently, the very nature of evolution has changed. In the Darwinian scheme, we can evolve only at the level of genes; however, with memes, a system of ideas can evolve by itself, without any biological change. Yet still, we see many of the same phenomena, with evolutionary fitness struggles and all—as when some philosophy evolves a new and convincing argument about why its competitors may be wrong. The interaction of meme propagation with Darwinian evolution has given rise to a new order of things. In particular, it makes possible such phenomena as "group selection" that are less well supported in simpler species. I don't see this much appreciated in the thinking of most other evolutionists, but I and many of my friends consider it an idea of tremendous importance.

BRIAN GOODWIN: Richard Dawkins and I see things in a very different mode, because he's made himself the proponent of Darwinism. For him, Darwin was a revelation. Dawkins was a zoologist, an ethologist,