SuperCooperators

Altruism, Evolution, and Why We Need Each Other to Succeed

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with Roger Highfield

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CHAPTER 14

Crescendo of Cooperation

Die liebe Erde allüberall
Blüht auf im Lenz und grünt aufs neu!
Allüberall und ewig blauen licht die Fernen,
Ewig . . . ewig . . .
—Mahler, *Das Lied von der Erde*

"Imagine a work so large that it mirrors the entire world." With this evocative sentence, Gustav Mahler summed up his ambition to create a new kind of music. The Austrian composer wanted to write symphonic works of such remarkable scope and magnitude that they could summon the fundamental forces that created the cosmos from the void. True to his word, Mahler's compositions are epic and heart-stopping. They are about life, death, love, and redemption. They are universal statements about the human condition, from its highest, brightest glory to its lowest, blackest folly.

Mahler took his own struggles with the vicissitudes of life and channeled these visceral experiences, along with his hopes and fears, into monumental orchestral works. He used his music to wrestle with the primeval moment of creation, even with the fundamental forces of evolution itself. He hoped that in some way he himself would become an instrument that could be played by the whole universe. I find his music, its huge breadth and its all-encompassing ambition, a tremendous and enduring inspiration.

Of all his works, one of the most striking is Symphony no. 8, which was dedicated to his wife, Alma. A work of reconciliation, the symphony celebrates the redemptive power of love. The première took place in Munich on September 12, 1910, and featured a chorus of about 850, with an orchestra of 171. In recognition of its epic scale, Mahler's agent nicknamed the work *Symphony of a Thousand.* Even today, the logistical demands of this work put it beyond the regular run of concert life and make any airing of it a major event, a striking tribute to creativity and cooperation as a battalion of musicians explore its complexity, its overwhelming intensity, and its sheer expressive joy. The opening theme of this grandest of all symphonies was articulated to fit the words *Veni, creator spiritus*—"Come, Creator Spirit." The second part is the apotheosis of Goethe's Faust.

Over the past decades I have voyaged through distant and diverse areas of science to seek out what I believe is the most creative force of biology, the one we know as cooperation. It is manifested at every level of human society, from an orderly queue of strangers at a railway station to the organization of a rock concert at a Super Bowl. The degree to which we cooperate sets us apart from the rest of creation. This is the fundamental reason humans have managed to eke out a living in almost every ecosystem on Earth and indeed have started to venture well beyond Earth. But, of course, this raises all kinds of questions, which I have examined in earlier chapters—not least, the one that troubled Darwin himself: In the ceaseless competition for food, territory, and mates, why would one individual go out of its way to help another?

Cooperating with many dazzling people over two decades, I have studied various ways in which evolution leads to cooperation in our highly competitive world. The basic issue that we have explored can be couched in terms of cost and benefit. A cooperator pays a cost for another individual to receive a benefit. If the cost is larger than the benefit, then cooperation is not productive and the game is not a cooperative dilemma. In this case, two cooperators would be worse off than two defectors. But if the benefit is larger than the cost, then we end up with a familiar game, the Prisoner's Dilemma.

Here is the problem that is central to the Prisoner's Dilemma. In

the simplest version of the Dilemma, without making any additional assumptions, natural selection favors defectors. As mentioned before, cooperators always have a lower fitness than defectors in a well-mixed population. As a consequence, as that population evolves, natural selection slowly increases the abundance of defectors until every last one of the cooperators has been exterminated. This is the "wrong" outcome, because a population of cooperators has a higher productivity (higher average fitness) than a population of defectors. Hence in this particular case natural selection does not achieve the highest fitness but actually destroys what would be best for the entire population. To favor cooperation, natural selection needs help. It needs mechanisms for the evolution of cooperation.

At present, we know five mechanisms for the evolution of cooperation. I have studied how these mechanisms work by blending game theory with evolution, assuming that the payoff from a game affects reproductive success. This means that, as the players mutate and evolve, natural selection smiles on players that have a high payoff. They reproduce relatively more in the struggle for existence, while fellow players that are unsuccessful dwindle and then die off.

I do not restrict the use of the term "natural selection" to genes alone. Depending on whether we talk about cells, animals, or people, reproduction can be genetic or cultural. In the former case, successful individuals leave more offspring and pass more genes on to future generations. In the latter, successful ideas, fashions, and strategies spread by imitation and learning: a fad is born. As one example, the concept of Darwinian evolution itself does not spread genetically but culturally, leaping from the mind of one biologist to infect another.

My work shows how cooperation arises out of competition, even though the two are locked together in ceaseless conflict. The collective effort of society depends in part on suppressing the ability of the individual to mutiny and defect. The same goes for rebellious cells, chromosomes, and genes. Like day and night, or good and bad, cooperation and competition are forever entwined in a tight embrace.

MECHANICS OF COOPERATION

To reap the rewards of cooperation there has to be at least one mechanism at work to counter the relentless and depressing tendency of natural selection to grind down the average fitness of a population in the Prisoner's Dilemma. In the opening chapters, I described five such mechanisms and how they can make us work together:

1. *Repetition* (direct reciprocity), "I'll scratch your back and you scratch mine." This accounts for the success of Tit for Tat–like strategies, whether those of the little fish that offer cleaning services on coral reefs, generous vampire bats that share blood meals, or the military units that policed the unofficial truces that emerged on the Western Front in the First World War, where an accidental infraction was met with a revenge raid or barrage. As the great eighteenth-century Scottish philosopher David Hume wrote in *A Treatise of Human Nature* in 1740: "I learn to do service to another, without bearing him any real kindness: because I foresee, that he will return my service, in expectation of another of the same kind."

   We also saw how, when there are mistakes caused by trembling hands and fuzzy brains, it is better to depend on strategies such as Generous Tit for Tat or Win Stay, Lose Shift. Relative to the former, the latter is the even simpler idea of repeating your previous move whenever you are doing well, and changing when the going gets tough. I described how, overall, direct reciprocity can lead to the evolution of cooperation only if the probability of another encounter between the same two individuals exceeds the cost-to-benefit ratio of the altruistic act; that's our first simple rule.
2. *Reputation* (indirect reciprocity). This mechanism of cooperation thrives when there are repeated encounters within a group of players. Now my behavior toward you also depends on what you have done to others. To get any return from being nice to someone, we must place our faith in forthcoming encounters: "Give and it shall be given unto you," as Luke put it in the Bible. One can sum up this mechanism with the phrase "I scratch your back and someone will scratch mine."

In human society, indirect reciprocity relies to a great extent on communication. In chapter 2, I explained how language might be needed to learn from the experiences of others and thereby establish the reputation of people, as well as pass it on again. We found that indirect reciprocity can only promote cooperation if the probability of knowing someone's reputation exceeds the cost-to-benefit ratio of the altruistic act; that's our second rule.

3. *Spatial selection*. This process occurs on the chessboard of life or in the spider's webs of social networks or the myriad sets that we all belong to. At the heart of any evolutionary process is a population of reproducing individuals, and the work of many scholars over the years has shown how the structure of that population can affect evolution. Whether we are talking about spatial structures or social networks or tags, all we mean by this is that some individuals interact with each other more often than others. Now cooperators can prevail by forming networks and clusters in which they help each other. Just as a gravitational lens bends the light of a galaxy, so the structure of a population bends the trajectory of evolution. A surprisingly simple rule determines whether cooperation can bud and flower on graphs. The benefit-to-cost ratio must exceed the average number of neighbors per individual. That's our third rule.
4. *Multilevel selection*. This mechanism recognizes how, in some circumstances, selection acts not only on individuals but also on groups. A group of cooperators might be more successful than a group of defectors. No one sums up this mechanism of cooperation better than Darwin: "There can be no doubt that a tribe including many members who . . . were always ready to give aid to each other and to sacrifice themselves for the common good, would be victorious over other tribes; and this would be natural selection." Multilevel (group) selection allows the evolution of cooperation, provided that one thing holds good: the ratio of the benefits to cost is greater than one plus the ratio of group size to number of groups. Thus this cooperative mechanism works well if there are many small groups and not so well if there are a few large groups—our fourth rule.
5. *Kin selection*. Here the bonds of family and of common ancestry are

decisive. I recognize my kin and I behave accordingly, so that I cooperate with close kin and I defect with strangers. Another common way to express this drive to look after one's own, genetically speaking, is to say that blood is thicker than water. This is summarized by Hamilton's rule, which states that the coefficient of relatedness must exceed the cost-to-benefit ratio of the altruistic act; this is our fifth rule. Although I have discussed the problems of this approach in chapter 5, I still believe that kin selection is a valid mechanism if properly formulated.

There we have it. Using these five mechanisms of cooperation, natural selection has ensured that we are able to get more from social living than from the pursuit of a solitary, selfish life. Thanks to these mechanisms, the essentially competitive drive of evolution can, in many circumstances, give rise to cooperation. Because our instincts have been shaped in this way over the generations, it is no surprise that one corollary of this is that universal behaviors—such as love, friendship, jealousy, and team spirit—are seen across all human societies.

If cooperation thrives due to the mechanism of multilevel selection, for example, then although there might always be an incentive to defect, those groups who have a higher percentage of people willing to sacrifice themselves for the greater good can do better. A nation, cult, or a religion can be seen as a group that is bound by the way that an individual makes sacrifices to help his brethren.

In direct or indirect reciprocity, we can glimpse the traditional idea that "one good turn deserves another." What I find amazing is that these calculations show that despite nature's competitive setting—based on natural selection—the winning strategies of direct and indirect reciprocity must have the following "charitable" attributes: be hopeful, generous, and forgiving. Hopeful here means that if I meet a newcomer then I hope that I can establish the basis of cooperation with him by making an effort to cooperate. Forgiving means that if someone defects, then I will work hard to reestablish a relationship based on cooperation. Generous means that in most of my interactions with other people, I do not adopt a myopic perspective. I do not moan

about who is doing better than me and who is getting the bigger share of the pie. Instead, I am content with equal or even slightly smaller shares but enjoy many productive and helpful interactions overall; now many more pies get shared.

In this way, my work on cooperation highlights which kinds of behaviors are important for human evolution and success in daily life. We have five mechanisms that can work separately and together to help everyone to get along. What is remarkable is that from an analytical, quantitative, and mathematical basis I can come up with ideas that should seem as familiar to secular ethicists as they are to followers of religions.

Diverse faiths are united by the reciprocity of the Golden Rule, as we saw in chapter 2. Evolution, which at first glance seems to present problems for faith, actually hones selfless, altruistic, and perhaps even saintly behavior. The teachings of the great world religions have much in common in that they provide ancient recipes for how to lead a fulfilled life. For millennia they have analyzed the human condition to ameliorate suffering and sadness. They have come to the conclusion that love, hope, and forgiveness are essential components of what is needed to solve the biggest problems. They call for unselfish action. Jesus says if you give, then your left hand should not know what your right hand is doing. Krishna says to the prince Arjuna in the Bhagavad Gita: You have to see yourself in every creature. You have to experience the sufferings of others as your own. For those who follow a faith, the solution comes when the drive to be selfish is overwhelmed by love. In the language we have encountered in this book, the teachings of world religions can be seen as recipes for cooperation. Now, for the first time, aspects of these powerful ideas have been quantified in experiments, captured in equations, and enshrined in science.

THE NEXT STEP FOR MANKIND

Mahler's Third Symphony chimes with my quest to understand the ultimate manifestation of cooperation, the 4-billion-year story of life on Earth. Written between 1893 and 1896, this is the composer's

longest piece—a performance lasts almost two hours. The symphony is a pantheistic vision of the universe, a gigantic musical poem, a hymn to the natural world in the form of a step-by-step ascent of the great Ladder of Creation.

My love of this symphony dates back to my early years in Oxford, at the start of the 1990s. One day my new student, Sebastian Bonhoeffer, asked me if I would like to go to a concert in the Sheldonian Theatre, a seventeenth-century building by Christopher Wren that is one of the architectural jewels of Oxford. Sebastian, himself an excellent musician (and now a biology professor at the ETH in Zürich), took me to hear a performance of Mahler's Third, in which he played the lead cello. I came and I listened. It was my first encounter with the great composer. On the uncomfortable wooden seats of the Sheldonian, my whole life unfolded. I never felt the same way about music again.

Mahler begins with a slow, primeval opening that evokes inert matter—rocks and inanimate nature—and gradually accelerates so that it becomes rousing and pounding. Life then marches in. The symphony passes onward and upward through more elaborate stages of evolution—flowers, animals, and mankind—before reaching divine love, which Mahler imagined as a supremely transcendental force.

From the movement "What the Rocks Tell Me" to "What Love Tells Me," from the first awakening of antediluvian life to the final exultant moments of this huge work, Mahler hoped that "nature in its totality may ring and resound." He achieved his aim. On its first complete performance on Monday, June 9, 1902, in Krefeld, the work was received with thundering acclaim, marking a rare moment in Mahler's life.

One of his letters describes how in the symphony "Nature herself acquires a voice and tells secrets so profound that they are perhaps glimpsed only in dreams!" In my own way, I would like to think I have helped to give nature her voice too. I find it more nuanced and more subtle than the one revealed by reflecting on competition alone. I have argued that evolution "needs" cooperation if she is to construct new levels of organization, driving genes to collaborate in chromosomes, chromosomes to collaborate in genomes, genomes to collaborate in

cells, cells to collaborate in more complex cells, complex cells to collaborate in bodies, and bodies to collaborate in societies.

After this grand tour of the mechanisms of cooperation, I have been struck—perhaps awestruck—by the extent to which humans cooperate. We use each and every mechanism that I have outlined, and to a remarkable degree. Sure, elements of every mechanism of cooperation can be glimpsed in other animal societies: multilevel selection among the ants, reciprocity among fish, spatial selection in colonies of bacteria, and so on. But no animal species can draw on the mechanisms to the same extent as seen in human society. Even our closest relatives, the apes, lack full-blown language and thus lack the full potential of indirect reciprocity.

While bacterial films may divide up labor across a single community, the complexity of this microbial cooperation pales in significance when compared to the complexity of human society that thrives in a modern city. While ants have a handful of castes, our society specializes to an extreme degree: from policemen and CEOs to soldiers to butchers, bakers, and candlestick makers. As Adam Smith recognized, using the example of a pin maker, the degree to which labor is divided up among the members of our society is extraordinary. What we learned in chapter 11 was that by rewarding successful cooperation, rather than by punishing defection, we can propel this cooperative effort to being truly creative and innovative. Working together this way, we can achieve things as a society that no individual ever could.

What makes us truly special is that cooperation through indirect reciprocity propelled the emergence of human language and brought about a new mode of evolution. We are now subject to an evolutionary dynamic that can detach itself to some degree from its genetic basis, from chemistry, genes, and DNA. This is cultural evolution, which involves learning, and explains why we are so devastatingly successful. As a result, the way the human brain evolves is utterly different from the evolution of any other biological structure that has ever existed. The architecture of the brain changes every time we talk to another person. We are able, in turn, to impose structural changes on the way the listener's brain is wired. The next time you listen to another person, remember

that you have permanently changed the wiring of your brain and will do this every time you memorize a moment, no matter how fleeting.

Although this special ability makes human society breathtakingly cooperative, it can hardly be claimed that we live in a cooperative utopia. The last century saw hundreds of millions of deaths in civil conflict, world wars, and genocides. That effort to wage a war can be seen as a perverted form of cooperation. The people of one side join forces against the other in an organized effort that all too often leads to destruction. There is always antagonism and rivalry. There is always the danger that a new war will rage. Where there is cooperation, there is also the danger of exploitation. Defectors loom in the dark. Ready to strike. Waiting for the right opportunity to pounce and to take advantage. As shown since the very first simulations that I conducted decades ago with Karl, there are always oscillations. Cooperation comes and goes, waxes and wanes. It has to be reborn in endless cycles.

Today, mankind is teetering on the brink of several possible catastrophes of its own making. The danger of nuclear conflagration has not gone away but become so familiar and unfashionable that, relative to the size of this threat, it is hardly remarked upon. The cold war stockpiles of vast numbers of warheads persist to a significant extent. We still face a doomsday scenario where nuclear war—one started deliberately or accidentally—could throw so much dust, debris, and smoke into the air that it would block life-giving sunlight from our atmosphere, causing a "nuclear winter." In June 2005, Senator Richard Lugar, then the Republican chair of the Senate Foreign Relations Committee, asked about the prospect of a nuclear attack within the next decade. The seventy-six nuclear security experts he polled came up with an average probability of 29 percent. Four respondents estimated the risk at 100 percent, while only one estimated it at zero. As nuclear weapons continue to proliferate and as terrorism becomes increasingly organized, this danger has grown.

The recent slump in the global economy has given us a glimpse of what might happen if there was a collapse. Existing economic policies are based on the theory that the world is made up of a patchwork of simple, largely separate markets. Yet money can now flow more easily

from country to country. This has stimulated global trade and prosperity, but it also means that an upset in one place can have major and unpredictable consequences elsewhere. The rapid increase in cross-border investments in recent decades is what allowed a local shock—the collapse in inflated U.S. real estate values—to propagate globally in 2008, especially through highly indebted investment companies that can respond to a loss of money in one place by withdrawing credit anywhere. In the event of financial Armageddon, world economies would slide into a punishing depression, perhaps worse than the Great Depression of the 1930s, when millions starved.

We are also staring into the abyss of environmental catastrophe, the ultimate Tragedy of the Commons. The Earth has a fever. And that fever is rising. The signs of climate crisis are now clear, from the drastic disappearance of the North Polar ice during the summer to faster-melting glaciers and the inundation of low-lying Pacific islands. There's a host of associated problems, from the water shortages facing cities in North and South America, Asia, and Australia to the spread of disease to problems with global food supply to an acceleration of the pace of extinction, as the web of life on which we depend is being torn, frayed, and shredded.

In his speech to accept the Nobel Peace Prize, Al Gore cited an African proverb that says, "If you want to go quickly, go alone. If you want to go far, go together." He gave a clarion call for cooperation. "We must abandon the conceit that individual, isolated, private actions are the answer. They can and do help. But they will not take us far enough without collective action." To put it another way, we are all prisoners of the same dilemma that ensnared myself and Karl years ago. And to solve apparently intractable issues such as climate change will take more than technology alone.

The danger is very real. I believe that intelligent life is fragile. I think that life has evolved in the universe often and has done so for the 13.7 billion years that our cosmos has been in existence. But, as far as we can see, we are alone. Intelligent life does not seem to stay around for long. This should give us pause for thought. Now, more than ever, we need to cooperate, and on a global scale. Although we are teetering on the brink of disaster, we are also on the brink of advancing to the next

level of cooperation. We need a climate program beyond even the vast scale of the Manhattan Project, in which we mobilize our civilization with the kind of resource and resolve that have previously been seen only when nations mobilized for a world war.

In previous chapters, I described how new opportunities to cooperate are able to drive creativity. When competing units on one level of organization begin to cooperate, new and creative levels of organization evolved, first between molecules, then simple cells, complex cells, multicellular creatures such as people, and, finally, between societies. I believe that climate change will force us to enter a new chapter of cooperation.

At this very moment, people worldwide are linked together to an extent that is incredible by the standards of what came before. There are endless connections being forged and changed and sundered by the technology of modern communications, whether phones, mobiles, iPhones, BlackBerries, Androids, computers, or the web. At the same time, we now understand what it takes to work together better than ever. I hope that we can harness the new understanding of cooperation to rise to the challenges of our crowded, nuclear, feverish world.

THE ETERNAL SYMPHONY

Music is the pleasure the human mind experiences from counting without being aware that it is counting.

—Gottfried Leibniz

Though the ambition of the magnificent Third Symphony most closely matches the agenda of my research, the Mahler composition that I adore the most of all is *Das Lied von der Erde* (*Song of the Earth*). The inspiration for this work for voice and orchestra—a "song-symphony"—came from *The Chinese Flute,* a translation of ancient Chinese poetry by the German poet Hans Bethge. On reading Bethge's version, Mahler was moved by its vision of beauty, transience, and death. After completing the great orchestral work that this poetry inspired, he wrote that "it is

probably the most personal composition I have created thus far." This was clear to his friend, conductor and composer Bruno Walter, when he first read the score.

When Walter saw how much of himself Mahler had poured into this transcendent work, he broke down and wept. The piece is suffused with a sense of mortality. This is hardly surprising. The summer before, in 1907, Mahler had been pushed, partly by anti-Semitism, to resign his post as director of the Vienna Court Opera, his eldest daughter Maria had died, and he himself was diagnosed with a serious heart defect.

In the second movement, Mahler refers to the death of his daughter ("a little light has gone out"), a shattering loss that he never came to terms with. The music tries to come to a resolution. It gets close but it can never quite make it. Like the Prisoner's Dilemma, it cannot ever be fully resolved. But, at the end of the last movement, Mahler finally becomes reconciled with his own death: "I will no longer travel into the distance. My heart is quiet and it is waiting for its hour." Reflecting on his own fate, he lets go.

Mahler was anxious about calling this work a symphony, fearing that like Beethoven and Bruckner before him, the ninth would be his last. Despite his unease, he dared to follow *Das Lied von der Erde* with a work entitled Symphony no. 9. Mahler had joked that he had cheated death as the new symphony was really his tenth. It turned out that his superstition would come true—the Ninth Symphony did prove to be his last completed work. A few months after Mahler's death in 1911, Bruno Walter led the first performance of *Das Lied von der Erde* in Munich.

A remarkable and famous reprise would be staged decades later, in 1952, when Walter returned to the piece with the Vienna Philharmonic Orchestra and the British singer Kathleen Ferrier, who had by then been diagnosed with breast cancer. The first time Ferrier performed the work she was overwhelmed by pain and raw emotion. She was unable to sing the final words of the final movement, "The Farewell." The music seems to evaporate into the ether, marking Mahler's final acceptance of death. The orchestra was touched and with Ferrier gave the performance of a lifetime. She lost her battle with cancer seventeen months later, at the age of forty-one.

All this may sound somber. But in the darkness of the symphony a chink of brilliant optimism can be glimpsed, along with a sense of surprise, which Mahler signals with a final change into the key of C major. At the moment that Mahler is reconciled with his own mortality, he understands how extinction will be followed by a new spring. This carries a deep resonance for me and my work.

Although *Das Lied von der Erde* underlines the fact that there's no escape for the individual from the blackness of death, life itself is reborn endlessly. As the music dwindles and dies away into nothingness, the teeming beauty of the world lives on. At the end, the earth is renewed in spring, everywhere and forever shining blue and bright. This final movement affects me deeply. Our world of change reflects an unchanging underlying reality that can be captured with mathematics. And just as the beauty of the world lives on beyond those final haunting moments of *Das Lied von der Erde,* so the laws of nature live on too.

The story of humanity is one that rests on the never-ending creative tension between the dark pursuit of selfish short-term interests and the shining example of striving toward collective long-term goals. I believe we now understand how defection in the Prisoner's Dilemma can be trumped by cooperation. And, just as Mahler ends on an upbeat note, so I believe the emphasis on cooperation puts a more optimistic sheen on life than the traditional take on Darwin, which condemns all life to a protracted and bloody struggle for survival and reproduction. Mutation and natural selection are not enough in themselves to understand life. You need cooperation too. Cooperation was the principle architect of 4 billion years of evolution. Cooperation built the first bacterial cells, then higher cells, then complex multicellular life and insect superorganisms. Finally cooperation constructed humanity.

I propose that "natural cooperation" be included as a fundamental principle to bolster those laid down by Darwin. Cooperation can draw living matter upward to higher levels of organization. It generates the possibility for greater diversity by new specializations, new niches, and new divisions of labor. Cooperation makes evolution constructive and open-ended.

Today we face a stark a choice: we can either move up to the next stage of evolutionary complexity, or we can go into decline, even become extinct. Though global problems loom large, we could be on the verge of the next transition in social organization, one of equal significance to the emergence of the first cell, of the first complex cell, or indeed of the very first multicellular creature. We have the understanding and, thanks to the remarkable extent to which our society is interconnected, we can build on it.

We are SuperCooperators. We are the only species on Earth that is able to draw on the support of all five mechanisms of cooperation, and we already do this to a remarkable extent. But we now have to do even better. We now have to strive to achieve the full potential of these mechanisms if we are to rise to the serious challenges that lie ahead.

Direct and indirect reciprocity will always play a critical role in routine dealings with others: the more help we give, the more we will receive. This aspect of human cooperation is as important as it is ancient. We are the only species that utilizes full-blown indirect reciprocity, because of our powerful and flexible language. When evaluating the reputation of another individual, animals must rely on direct observation. But, using language, humans can learn from the experiences of others. We can put a name to the face of someone and use it to create a reputation.

Reputation is a potent force that can be harnessed to avoid the Tragedy of the Commons. Success depends on freedom of information without censorship and spin. We need detailed information on the degree to which people, companies, or countries squander precious resources. We need to know the true environmental cost of everyday items, from a boiler to a car, so that we can build it into the price tag. We need to know the actual risks of climate change, without deviation, embellishment, or exaggeration.

Over the years we have spun ever expanding webs of indirect reciprocity from villages, to cities, states, and across the entire globe. Now, because of the high connectivity of our global networks, the reputation that is associated with a name can move around the planet in a matter of minutes. If someone has a great idea in Asia, a fellow scientist in the United States can learn about it instantly. If a thought-provoking blog is posted online, it can be disseminated, translated, and discussed

worldwide that day. If a catchy new song is available for download, it can be played as easily in the main street of a little town as the back street of a vast urban ghetto.

Many of my own collaborations are with people who live on other continents. But because of email, Skype, phone, and so on, it is as if they are sitting in the room next door. My room in the woods of New England is as close to Cambridge as to Roger's home in London or to Hisashi's office in Tokyo. In this way, productive ideas and innovations can spread far and wide. Today, there are innumerable ways by which cooperation can flourish.

But with new opportunities come new dangers. All my work on the evolution of cooperation hints at one inevitable feature: there is no such thing as utopia and the degree of cooperation in a society will fall as inevitably as it will rise again. With globalization, the planet's resources are becoming exhausted. With globalization, the never-ending competitive quest to achieve economic growth is unsustainable. With globalization comes uniformity too, which makes us more vulnerable to jolts. As has been seen in the financial world, there is no longer safety in investing in diversified American, European, and Asian stocks. They are all interconnected, and when a financial collapse hits one market, they can all plunge into a nosedive. For the same reason, we are more vulnerable to pandemics: thanks to international air travel, a disease can quickly become established and spread around the world.

We cannot expect cooperation to endure forever. But we can hope to prevent a drastic fall, or at least ensure that cooperation is more likely to prevail over longer periods of time and only suffer the occasional breakdown. We can work to quickly reestablish cooperation after each collapse.

We need to place more faith in citizens than leaders. Cooperation has to come from the bottom up and not be imposed from the top down. That is why, for example, democracy is a cornerstone concept, since this is a form of cooperation that grows from the roots. We need to do even more to create an environment where cooperation can flourish, if we are to reap its creative benefits.

Another lesson of my analysis of the mechanisms of cooperation over

the years is that we have to learn not to be too inward looking, petty minded, and competitive. When it comes to the structure of society, for example, we have to step out of the narrow confinement of looking after our relatives, or our own kind. Kin selection (even if properly formulated) is only a small component of human cooperation. Nepotism is counterproductive when it comes to cultivating cooperation across wider swaths of society.

We have to look beyond the narrow idea that punishment and threat can enforce cooperation. In my opinion, creative cooperation can only come from helpful interactions such as participation, friendship, and reward.

We also discovered how we need to be more open to absorbing the lessons that lie behind the success of other people, rather than focus on our own immediate goals. By adopting the former extrovert strategy, rather than the introvert latter, we can ensure that best practice will become established.

And, of course, we need to remember the legacy of Hardin. We need to find new ways of thinking—a fundamental extension of morality—if we are to live within our terrestrial means. And that brings me to a point that I have already made, but one worth repeating. Down the years my research has told me that if we are to solve the Prisoner's Dilemma, we need to be generous, hopeful, and forgiving. Perhaps for the first time, the conclusions of science and mathematics can be seen to intersect with the teachings of world religions.

Humans are SuperCooperators. We are able to draw on all five mechanisms of cooperation. In particular, we are the only species that can summon the full power of indirect reciprocity, thanks to our rich and flexible language. We have names and with them come reputations that can be used to help us all to work more closely together. We can also design our surroundings—from architecture to laws to the internet and much more besides—to achieve more enduring cooperation. As a result, our ability to work together has the potential to rise even further to reach a new pitch of harmony and unity. Again I should stress that I mean more than simply cooperation today and in the here and now. Thanks to the extraordinary mechanism of indirect

reciprocity, language can unite the interests of the past, the present, and the future, too.

Many already like to talk of their duty to future generations. Discussions of sustainability focus on the idea of intergenerational equity—providing the next generation, and the ones that follow, with the same environmental potential as presently exists. Politicians often meditate on the legacy that they would like to leave to their grandchildren. I would like to push this idea to its logical conclusion and encourage everyone to think objectively about how they are cooperating with future generations. We need to broaden our horizon of concerns far beyond the events of tomorrow. We need our duty of care to extend to those who have yet to be born. We must do our utmost to cooperate with the many tens of billions of people who will inherit the world from us.

I am hopeful that, in the distant future, a SuperCooperator will gaze toward an infinite blue horizon of opportunities. If we take a cosmic view, there's hope for life. Across the universe I am sure there are thousands of societies, even millions, that are as advanced as our own, if not more so. Each one will no doubt use different approaches to solve the problem of efficient global cooperation. Some will work. Others will fail.

A higher level of selection will operate among them. Some civilizations will expand and prosper in the long term. Many will not and may well perish and wink out. And there are other fates in store. A few will lose their home world only to colonize new planets. Some may die off but leave a new kind of life in their wake, a spacefaring flotilla of intelligent robots that can reproduce, thrive, and explore their galaxy. Those civilizations that have solved the problem of cooperation will persist in the cosmos. We can only hope that this list of successful SuperCooperators will include those carbon-based life forms that we call human beings. In this great adventure, everyone has a role to play. Success depends on all of us. Over to you.

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The first time I talked about the "five rules for the evolution of cooperation" was at a conference held in March 2006 at the Zoology Department at the University of Oxford in honor of the seventieth birthday of my great friend and mentor, Lord May of Oxford. The warmth and enthusiasm that greeted my lecture was a great reminder of the place where I had been so happy for many years.

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