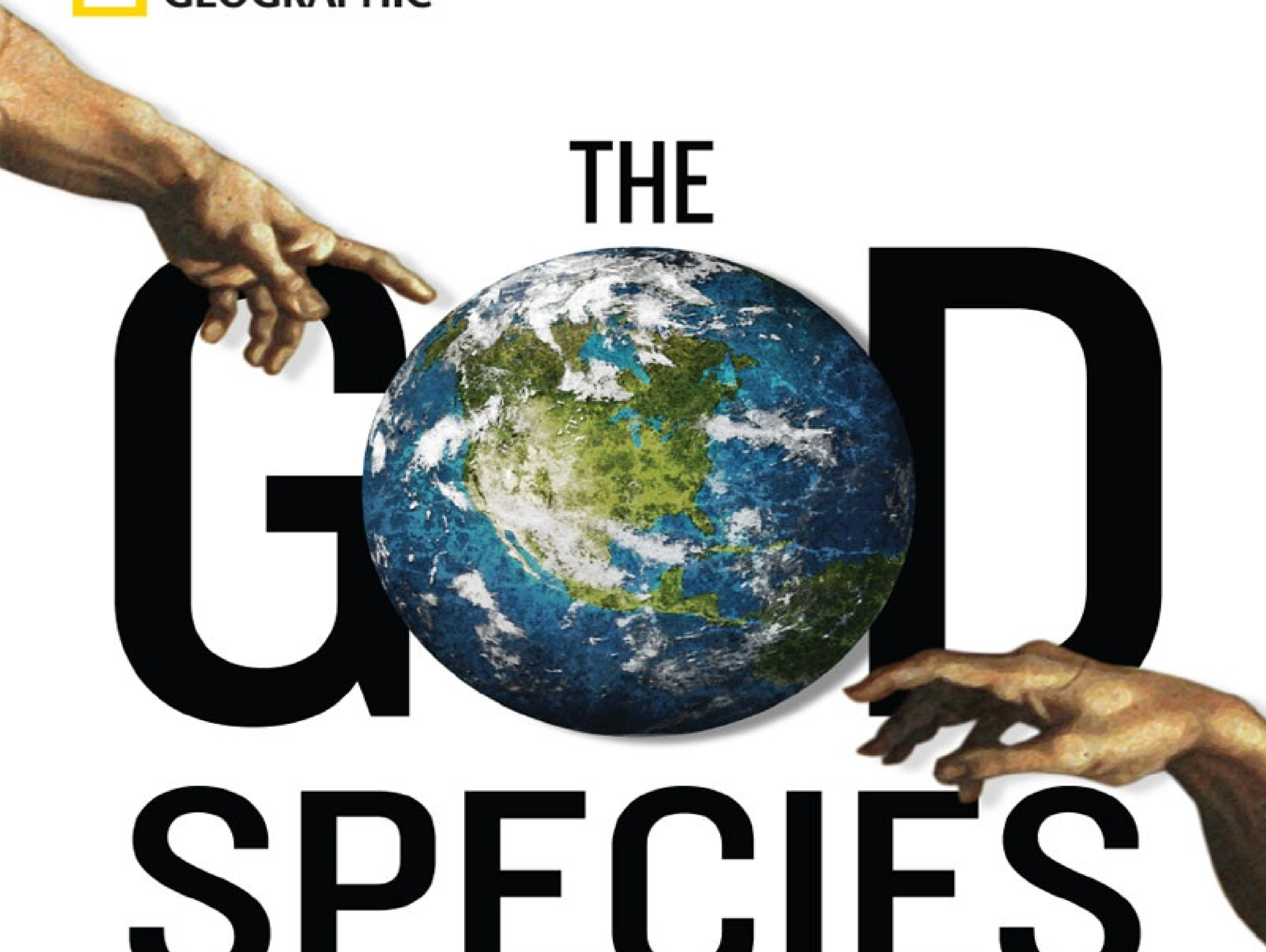
NATIONAL GEOGRAPHIC

THE GOD SPECIES



SAVING THE PLANET IN THE AGE OF HUMANS

Author of *Six Degrees*

MARK LYNAS

By the same author

High Tide: News from a Warming World
Six Degrees: Our Future on a Hotter Planet

MARK LYNAS

THE GOD SPECIES

Saving the Planet in the Age of Humans

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For my family and other animals

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ACKNOWLEDGMENTS

This book is an unusual beast, because it is conceptually and scientifically based on the work of other people. It is traditional in acknowledgements for writers to gush that “without so-and-so this book would never have been written,” but in the case of Johan Rockström and his planetary boundaries co-authors this is literally true. The basic concept is entirely theirs, as are the scientific definitions and quantifications attached to each one. However, the evidence supporting the boundaries presented in this book is largely the fruit of my own research, and the social and economic implications I suggest that the boundaries may carry are my assertions alone. I have no idea whether Johan’s co-authors support nuclear power, carbon offsetting, or a variety of other controversial proposals that I explore o endorse in this book. They have laid the foundations, however, for a new and better way of looking at our planet, and for that we are all deeply in their debt.

I am particularly grateful to planetary boundaries co-author Professor Diana Liverman, a longtime friend of my family, who invited me to the first scientific workshop on the boundaries concept at the Tällberg Forum in Sweden. That kind gesture set me on this road, and Diana has also been consistently supportive throughout the long process of writing and publishing. As a Visiting Research Associate at Oxford University’s Environmental Change Institute (which Diana recently headed) I have also benefited enormously from all the research facilities, expert lecturers, and contacts of a world-class university. Most important of all was continuing access to the Radcliffe Science Library, both on-site and remotely: I am deeply grateful to all the helpful staff at the RSL fo their assistance and the computing staff who helped keep my VPN connection working through the hard times.

As always, I am indebted to my loyal and very companiable agent Antony Harwood, whose continuing input has been invaluable. The long, multiyear process of writing a book inevitably has its ups and downs, and I could not ask for a better agent or friend. At my publisher Fourth Estate, my editor Robin Harvie—himself an accomplished author—played the invaluable role of helping me see that this book was not quite finished when I thought it was, and has improved the end result immeasurably in the process. Copy editor Steve Cox’s succinct additions and deletions have benefite the manuscript hugely—I can only hope that one day I learn how to get “that” and “which” the right way round.

I don’t dare embark on a long list of friends and colleagues who have helped in case I leave someone important out. You know who you all are. Thank you. My wife Maria deserves a special mention though, as do my children Tom and Rosa. It is them—and our nonhuman friends of all kingdoms and phyla—to whom this book is dedicated.

PREFACE

Then Man said: "Let there be life." And there was life.

Thunderbolts do not come much more momentous than this: In May 2010, for only the second time in 3.7 billion years, a life-form was created on planet Earth with no biological parent. Out of a collection of inanimate chemicals an animate being was forged. This transformation from nonliving t living took place not in some primordial soup, still less the biblical Garden of Eden, but in a Californian laboratory. And the Divine Creator was not recognizably godlike, despite the beard and gentle countenance. He was J. Craig Venter, a world-renowned biologist, highly successful entrepreneur and one of the first sequencers of the human genome. At the ensuing press conference, this creator and his colleagues announced to the world that they had made a self-replicating life-form out of the memory of a computer. A bacterial genome had been sequenced, digitized, modified, printed out, and booted up inside an empty cell to create the first human-made organism. As proof, th scientists wielded photographs of the microscopic "*Mycoplasma mycoides* JCVI-syn1.0" cells, busily obeying the original divine command to be fruitful and multiply in one of the J. Craig Venter Center' many petri dishes. The new discipline of synthetic biology had come of age.

Forget all your fears about genetic engineering (GE); synthetic biology makes GE look as quain and old-fashioned as a horse and cart at a Formula One rally. Old-style biotech was about mixing and rearranging small numbers of existing natural genes from different species and hoping that the right thing happened. Synthetic biology is an order of magnitude more powerful, for it gives humanity the potential to design and create life from scratch. Venter and his team didn't quite achieve that: Their synthetic genome, after being stitched together with the help of some well-trained yeast, was transplanted into the empty cell of a closely related bacterium that was arguably already "alive," at least in form if not in function. But the structure the new cells took was that prescribed by the scientists, featuring specially designed DNA "watermarks" that included three quotes, the names of the researchers on the project, and an email address for anyone clever enough to successfully decode and sequence the new genome.

The next steps for Venter's team—and other competitors rushing to pioneer novel methods in th same field—point the way towards a new technology of awesome power and potential. Once the function of every gene is understood, scientists can begin to build truly new organisms from scratch with different useful purposes in mind. Microbial life-forms could be designed to create biofuels or new vaccines, to bioremediate polluted sites, or to clean water. In the hands of a modern-day Bond villain, they might also be used to forge virulent new superbugs that could wipe out most of the world's population. But the technology per se is ethically inert; it is just a tool. The purpose of a machine depends upon whose hands are wielding its power. Synthetic biology reduces the cell to a machine, whose components—once properly understood—can be assembled like blocks of Lego. Wh build a robot out of perishable steel and plastic when you can build a bio-bot that feeds itself, carries out its prescribed task, heals any injuries, and creates near-identical copies of itself with no outside intervention?

The Book of Genesis is full of instances of humans being punished for their attempts to become like God. After the woman and the serpent combine forces to taste the forbidden fruit from one tree, Genesis 3:22 the Lord complains: "See, the man has become like one of us, knowing good and evil; and now, he might reach out his hand and take also from the tree of life, and eat, and live for ever." Man is banished from Eden to deny him this power of immortality, but Genesis 11:3 once again finds humanity trespassing on the power of the divine, this time with a great tower aimed at reaching heaven. God's solution to the Tower of Babel was a smart one, achieved by dividing humans into mutually uncomprehending linguistic groups. Today, with the worldwide language of science, that problem has finally been overcome. Venter and his team have seemingly proved that all life is reducible to chemistry—there is nothing more to it than that. No essential life force, no soul, no afterlife.

With the primacy of science, there seems to be less and less room for the divine. God's power is now increasingly being exercised by us. We are the creators of life, but we are also its destroyers. On planetary scale, humans now assert unchallenged dominion over all living things. Our collective power already threatens or overwhelms most of the major forces of nature, from the water cycle to th circulation of major elements like nitrogen and carbon through the entire Earth system. Our pollutan have subtly changed the color of the sky, while our release of half a trillion tonnes of carbon as the greenhouse gas CO_2 into the air is heating up the atmosphere, land, and oceans. We have leveled forests, plowed up the great grasslands, and transformed the continents to serve our demands from se to shining sea. Our detritus gets everywhere, from the highest mountains to the deepest oceans: Abandoned plastic bags drift ghostlike in the unfathomable depths, even kilometers beneath the floating Arctic ice cap. Wherever you look, this truth is there to behold: Pristine nature—Creation—has disappeared forever.

There is a name for this new geological era. The Holocene—the 10,000-year, climatically equable post–ice age era during which human civilization evolved and flourished—has slipped into history, to make way for the Anthropocene. For the first time since life began, a single animal is utterly dominant: the ape species *Homo sapiens*. Evolution has equipped us with huge brains, stunnin adaptability, and brilliantly successful technical prowess. In less than half a million years we have gone from prodding anthills with sticks to constructing a worldwide digital communications network Who can beat that? Like Venter's bacteria, we have been extremely fruitful and multiplied prodigiously: Humans are now more numerous than any large land animal ever to walk the Earth, and the combined weight of our fleshy biomass outstrips that of most other larger animals put together, with the single exception of our own livestock. The productive capacity of a major part of the planet' terrestrial surface is now dedicated to satisfying our demands for food, fuel, and fiber, while the oceans are trawled around the clock for the fishy fats and proteins our brains and bodies demand. In sum, somewhere between a quarter and a third of the entire planetary "net primary productivity" (everything produced by plants using the power of the sun) is today devoted to sustaining this one species—us.

With close to 7 billion specimens of *Homo sapiens* currently in existence, mostly enjoying risin (though highly variable) levels of wealth and material consumption, human beings have so far been a evolutionary success story unprecedented in the entire history of planet Earth. But there is a dark side to this momentous achievement. For the biosphere as a whole the Age of Humans has been a catastrophe. Our domestication of the planet's surface to provide crops and animals for ourselves has displaced all competing species to the margins. The Earth is now in the throes of its sixth mass extinction, the worst since the ecological calamity that wiped out the dinosaurs 65 million years ago. Evolution is about competition—and we have outcompeted them all. No other species can control ou numbers and return balance to the system (though extremely virulent microbes are likely to come closest). Whenever we have appeared on the verge of shortages, either in food production or fuel for our ever-rising energy demands, we have saved ourselves through brainpower and the judicious application of technology. The worst plague, flood, or world war—which may singly or combined cause horrifying loss of life—is just a blip in this relentless upward trend.

But most amazing of all perhaps is how blissfully unaware of this colossal transformation we remain. We are phenomenally, stupendously, ignorant. As if God were blind, deaf, and dumb, we blunder on without any apparent understanding of either our power or our potential. Even most Green

—ever hopeful that vanished wild nature can one day be restored—still recoil from the real truth about our role. Climate change deniers are successful not just because of the moneyed vested interest they serve, but because they tap into a powerful cultural undercurrent that insists we are small and th planet is big, ergo nothing we do—not even in our collective billions —can have a planet-scale impact. The world's major religions, founded as they were in an earlier, more innocent age, share thi insistence, as if the Book of Genesis could still be anything more than a historical metaphor in an era of Earth science and biochemistry. Our culture and politics languish decades behind our science.

To most people my contention that humans are now running the show smacks of hubris. Consequently everyone loves a good disaster, because it makes us feel small. After the 2004 Asian tsunami there were honest discussions over the benevolence or otherwise of God. Those in the path o hurricanes often speak about the anger of Mother Nature. When the Icelandic volcano Eyjafjallajoku erupted in April 2010, news reports reminded us of "nature's awesome power over humans," as if a few grounded aircraft in Europe had humbled us helpless clumsy apes. The Japanese earthquake and resulting tsunami disaster in March 2011 showed nature's force at its most powerful and destructive, but many lives were saved because of warning systems and strict building codes. We may not be able to stop earthquakes, but the idea of perennial human victimhood is now somewhat out of date. I suspect there is a reason why most of us cannot bear to let go of it, however, for admitting that we hold the levers of power over the Earth's major cycles would mean having to make conscious decisions about how the planet should be managed. This is an idea so difficult to contemplate that most people simply prefer denial, relieving themselves of any inconvenient burden of responsibility. What you don't know can't hurt you, right?

This see-no-evil approach is particularly convenient for politically motivated climate-change deniers. Take Newt Gingrich, the U.S. Republican firebrand who almost single-handedly destroyed th Clinton Presidency and is now taking aim at Obama too. He told the American environment website Grist.org in June 2010: "It's an act of egotism for humans to think we're a primary source of climate change. Look at what happened recently with the Icelandic volcano. The natural systems are so much bigger than manmade systems."[1] QED, as I think they say.[2]

Gingrich and his ilk may be an extreme case, but this degree of ignorance and denial cannot go on for much longer. Instead, I suggest that since nature can no longer tame us, then we must tame ourselves. Recognizing that we are now in charge—whether for good or ill—we need to make conscious and collective decisions about how far we interfere with the planet's natural cycles and ho we manage our global-scale impacts. This is not for aesthetic reasons, or because I mourn the loss of the natural age. It is too late for that now, and—as my uncle always says—one must move with the times. Instead, the overwhelming weight of scientific evidence suggests that we are fast approaching the point where our interference in the planet's great biogeochemical cycles is threatening to endang the Earth system itself, and hence our own survival as a species. To avert this increasing danger, we must begin to take responsibility for our actions at a planetary scale. Nature no longer runs the Earth We do. It is our choice what happens from here.

This book aims to demonstrate how our new task of consciously managing the planet, by far the most important effort ever undertaken by humankind, can be tackled. The idea for it came to me in a moment of revelation two years ago in Sweden, during a conference in the pretty lakeside village of Tällberg. I was invited to join a group of scientists meeting in closed session to discuss the concept o "planetary boundaries," a term coined by the Swedish director of the Stockholm Resilience Centre, Professor Johan Rockström. The scientists—all world experts in their fields—were trying to nail dow which parts of the Earth system were being most affected by humans, and what the implied limits might be to human activities in these areas. Some, like climate change and biodiversity loss, were familiar and obvious contenders for top-level concern. Others, like ocean acidification and the accumulation of environmental toxics, were newer and less well-understood additions to the stable.

During hours of debate, and with much scribbling of numbers and spider diagrams on flip-chart paper, humanity’s innumerable list of ecological challenges was reduced to just nine. I left the room late that afternoon certain that something radical had just happened, but not quite sure what it was. It wasn’t until later in the evening—in the shower of all places—that I understood in a flash just how important the planetary boundaries concept could be. I realized that scientists studying the Earth system were now in a position to define what mattered at a planetary level, and that this knowledge could and should be the organizing basis for a new kind of environmental movement—one that left behind some of the outdated concerns of the past to focus instead on protecting the planet in the ways that really counted. Of course all knowledge is tentative, but here was something very tangible: For the first time, world experts were not just listing our problems, but putting numbers on how we shoul approach and solve them. I tracked down Johan Rockström and we shared a beer in the hotel lobby. H was encouraging, and we agreed that my job as a writer and as an environmentalist should be to do what the scientists could not: get this scientific knowledge out into the mainstream and demand that people—campaigners, governments, everyone—act on it. Hence this book.

The planetary boundaries concept of course builds on past work conducted by experts in many different fields, from geochemistry to marine biology. But its global approach is actually very new and potentially quite revolutionary. Unlike, say, the 1972 *Limits to Growth* report produced by the Club of Rome, the planetary boundaries concept does not necessarily imply any limit to human economic growth or productivity. Instead, it seeks to identify a safe space in the planetary system within which humans can operate and flourish indefinitely in whatever way they choose. Certainly th will require limiting our disturbance to key Earth-system processes—from the carbon cycle to the circulation of fresh water—but in my view this need constrain neither humanity’s potential nor its ambition. Nor does it necessarily mean ditching capitalism, the profit principle, or the market, as many of today’s campaigners demand. Above all, this is no time for pessimism: We have some very powerful tools available to allow us to live more gently on this planet, if only we choose to use them.

In this book I take the planetary boundaries concept further into the social, economic, and political realms than the original experts were able to. Although some of the planetary boundaries expert group have generously helped to check my facts and figures, I do not expect them to agree wit all my suggestions or arguments regarding the implications of meeting the boundaries. There are substantial caveats and uncertainties, as always, and disagreement can be expected between other experts about whether a “planetary boundary” is truly relevant, and if so, what its limit should be—n to mention how we should meet it. This is first-draft work, Planetary Boundaries 1.0 if you will; ther cannot fail to be teething problems. Even so, factual statements in this book are based wherever possible on the peer-reviewed scientific literature—the gold standard for current knowledge. References are at the end of the book, and I urge all readers to make good use of them.

Many will find my analysis and conclusions rather unsettling—not least my colleagues in the Green movement, many of whose current preoccupations are shown to be ecologically wrong. Until now, environmentalism has been mostly about reducing our interference with nature. Central to the standard Green creed is the idea that playing God is dangerous. Hence the reflexive opposition to nev technologies from splitting the atom to cloning cattle. My thesis is the reverse: playing God (in the sense of being intelligent designers) at a planetary level is essential if creation is not to be irreparabl damaged or even destroyed by humans unwittingly deploying our newfound powers in disastrous ways. At this late stage, false humility is a more urgent danger than hubris. The truth of the Anthropocene is that the Earth is far out of balance, and we must help it regain the stability it needs t function as a self-regulating, highly dynamic, and complex system. It cannot do so alone.

This means jettisoning some fairly sacred cows. Nuclear power is, as many Greens are belatedly realizing, environmentally almost completely benign. (The Fukushima disaster in Japan did nothing t change this sanguine assessment, and perhaps more than anything reconfirmed it; more on that later.) Properly deployed, nuclear fission is one of the strongest weapons in our armory against global warming, and by rejecting it in the past campaigners have unwittingly helped release tens of billions of tonnes of carbon dioxide into the atmosphere as planned nuclear plants were replaced by coal from the mid-1970s onwards. Anyone who still marches against nuclear today, as many thousands of peop did in Germany following the Fukushima accident, is in my view just as bad for the climate as textbook eco-villains like the big oil companies. (Germany's over-hasty switch-off of seven of its nuclear power plants after the Japanese tsunami will have led to an additional 8 million tonnes of carbon dioxide in just three months.[3]) The same goes for genetic engineering. The genetic manipulation of plants is a powerful technology that can help humanity limit its environmental impa and feed itself better in the process. I personally campaigned against it in the past, and now realize that this was a well-intentioned but ignorant mistake. The potential of synthetic biology I can only begin to guess at today in early 2011. But the lesson is clear: We cannot afford to foreclose powerful technological options like nuclear, synthetic biology, and GE because of Luddite prejudice and ideological inertia.

Indeed, if we apply the metric of the planetary boundaries to the campaigns being run by the big environmental groups, we find that many of them are irrelevant or even counterproductive. Carbon offsetting is a useful short-term palliative that the Green movement has discredited without good reason, harming both the climate and the interests of poor people in the process. Some Green groups have also made it very difficult to use the climate-change negotiations as a way to save the world's forests by insisting that rain forest protection should not be eligible for carbon credits. In addition, environmental and development NGOs in general have been much too easy on rapidly emerging big carbon emitters like China and India, whose governments need to be pressed or assisted to eschew coal in favor of cleaner alternatives. Blaming the rich countries alone for climate change may tick all the right ideological boxes, but it is far from being the full story.

Most Greens also emphatically object to geoengineering—the idea that we could consciously alter the atmosphere to counteract climate change, for example by spraying sulphates high in the stratosphere to act as a sunscreen. But the objectors seem to forget that we are already carrying out massive geoengineering every day, as a hundred million people step into their cars, a billion farmers dig their plows into the soil, and 10 million fishermen cast their nets. The difference seems to come down to one of intent: Is unwitting and bad planetary geoengineering really better than witting and good planetary geoengineering? I am not so sure. At the very least a reflexive rejectionist position risks repeating the mistakes of the anti-genetic engineering campaign, where opposing a technology a priori meant that lots of potential benefits were stopped or delayed for no good cause. Being against something can have just as big an opportunity cost as being for it.

Certainly deciding on something as epochal as intentional climatic geoengineering would involv us in some truly awesome collective decisions, which we have only just begun to evolve the international governance structures to manage. But if we want the Anthropocene to resemble the Holocene rather than the Eocene (roughly 55–35 million years ago, which was several degrees hotter and had neither ice caps nor humans) we will need to act fast. On climate change, meeting the proposed planetary boundary means being carbon-neutral worldwide by mid-century, and carbon-negative thereafter. The former will not be possible in my view without nuclear new-build on a large scale, and the latter will need the deployment of air-capture technologies to reduce the concentration of ambient CO_2. On biodiversity loss, we need to rapidly scale up "payments for ecosystem services," schemes that use private-and public-sector approaches to make planetary ecological capital assets lik rain forests and coral reefs worth more alive than dead. To meet the other boundaries we will need to rain forests and coral reefs worth more alive than dead. To meet the other boundaries we will need to deploy genetically engineered nitrogen-and water-efficient plants, remove unnecessary dams from rivers, eliminate the spread of environmental toxics like dioxins and polychlorinated biphenyls (PCBs), and get much better at making and respecting international treaties. We can learn a great deal from the success of ozone-layer protection, which remains a shining example of how to do it right.

Most importantly, environmentalists need to remind themselves that humans are not all bad. We evolved within this living biosphere, and we have as much right to be here as any other species. Through our intelligence, Mother Earth has seen herself whole and entire for the first time from space.[4] Thanks to us she can even hope to protect herself from extraterrestrial damage: We now operate a program to track large meteorites like the one that destroyed a significant portion of the biosphere at the end of the Age of Dinosaurs. The Age of Humans does not have to be an era of hardship and misery for other species; we can nurture and protect as well as dominate and conquer. But in any case, the first responsibility of a conquering army is always to govern.

INTRODUCTION

THE ASCENT OF MAN

Three large rocky planets orbit the star at the center of our solar system: Venus, Earth, and Mars. Tw of them are dead: the former too hot, the latter too cold. The other is just right, and as a result has evolved into something unique within the known universe: It has come alive. As Craig Venter and hi team of synthetic biologists have shown, there is nothing chemically special about life: The same elements that make up our living biosphere exist in abundance on countless other planets, our neares neighbors included. But on Earth, these common elements—carbon, hydrogen, nitrogen, oxygen, and many more—have arranged themselves into uncommon patterns. In the right conditions they can move, grow, eat, and reproduce. Through natural selection, they are constantly changing, and all are involved in a delicate dance of physics, chemistry, and biology that somehow keeps Earth in its Goldilocks state, allowing life in general to survive and flourish, just as it has done for billions of years.

Why the Earth has become—and has remained—a habitable planet is one of the most extraordinary stories in science. While Venus fried and Mars froze, Earth somehow survived enormous swings in temperature, rebounding back into balance whatever the initial cause of the perturbation. Venus suffered a runaway greenhouse effect: Its oceans boiled away and most of its carbon ended up in the planet's atmosphere as a suffocatingly heavy blanket of carbon dioxide. Mars on the other hand, took a different trajectory. It began life warm and wet, with abundant liquid water. Yet something went wrong: Its carbon dioxide ended up trapped forever in carbonate rocks, condemning the planet to an icy future from which there could be no return.[1] The water channels and alluvial fans that cover the planet's surface are now freeze-dried and barren, and will remain so until the end of time.

Part of the Earth's good fortune obviously lies in its location: It is the right distance from the su to remain temperate and equable. But the distribution of Earthly chemicals is equally critical: Our greenhouse effect is strong enough to raise the planet's temperature by more than 30 degrees from what it would otherwise be, from -18°C to about 15°C today on average—perfect for abundant life— while keeping enough carbon locked up underground to avoid a Venusian-style runaway greenhouse. Ideologically motivated climate-change deniers may rant and obfuscate, but geology (not to mention physics) leaves no room for doubt: Greenhouse gases, principally carbon dioxide (with water vapor a a reinforcing feedback), are unquestionably a planet's main thermostat, determining the energy balance of the whole planetary system.

This astounding four-billion-year track record of self-regulating success makes the Earth unique certainly in the solar system and possibly the entire universe. The only plausible explanation is that self-regulation is somehow an emergent property of the system; negative feedbacks overwhelm positive ones and tend to push the Earth toward stability and balance. This concept is a central plank of systems theory, and seems to apply universally to successful complex systems from the internet to ant colonies. These systems are characterised by near-infinite complexity: All their nodes of interconnectedness cannot possibly be identified, quantified, or centrally planned, yet their product a a whole tends toward balance and self-correction. The Earth that encompasses them is the most complex and bewilderingly successful system of the lot.

One of the pioneers in understanding the critical regulatory role of life within the Earth system was the brilliant scientist and inventor James Lovelock. Lovelock's original Gaia theory—that living sample content of The God Species: Saving the Planet in the Age of Humans