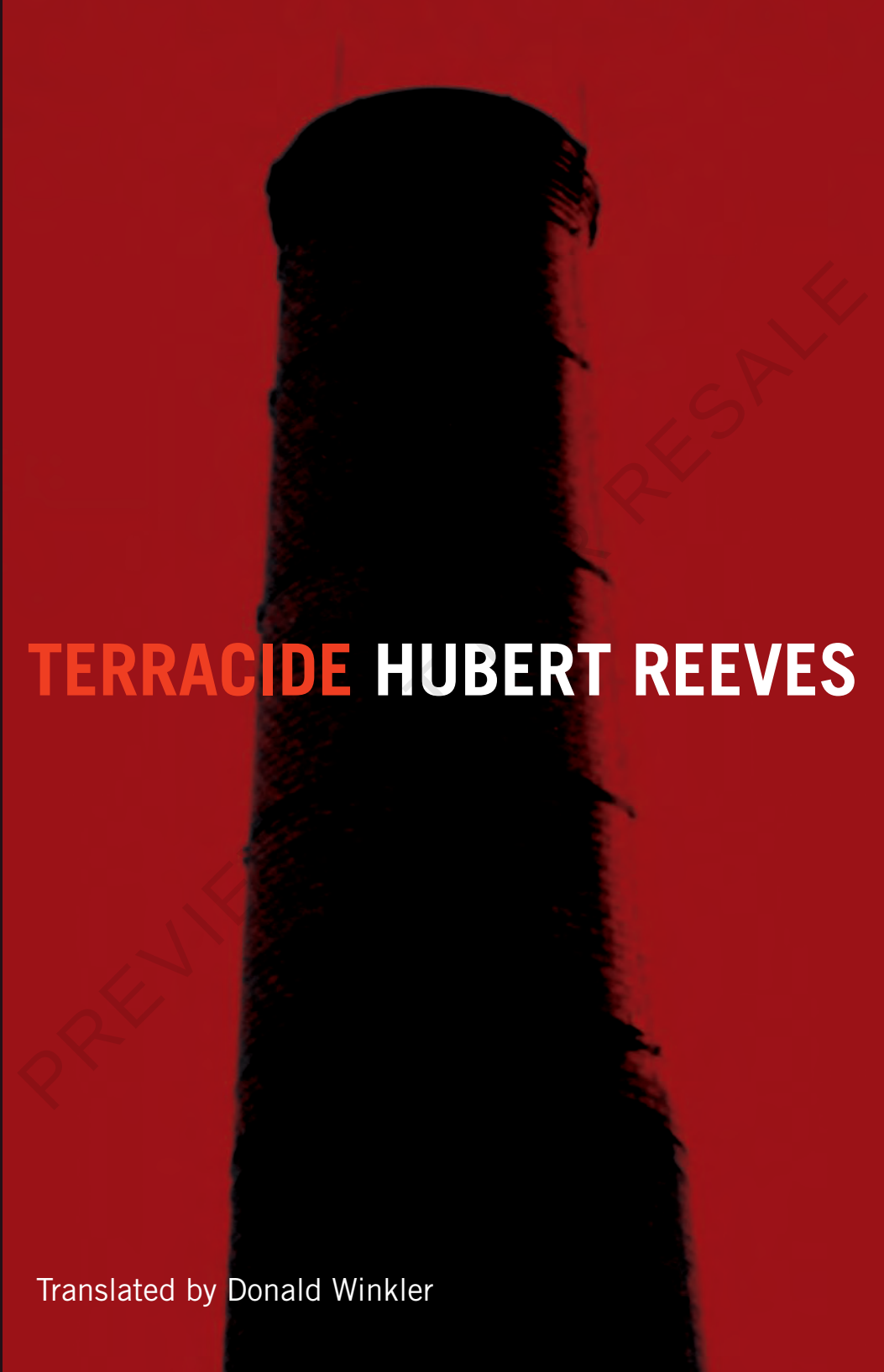
TERRACIDE
HUBERT REEVES
Translated by Donald Winkler

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PREVIEW NOT FOR RESALE

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This book is dedicated to
Camille Scoffier-Reeves, my wife,
with enormous gratitude for her expert assistance
and her invaluable contribution to
my writings over the last twenty-five years.

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PREFACE

THIS BOOK WAS FIRST WRITTEN and published in French under the name *Mal de Terre* in 2003. It sold over fifty thousand copies in France, Belgium, Switzerland, and Canada. In 2005, revisions were made, and up-to-date information was added. Due to complicated circumstances, it has taken longer than was hoped for this English translation to appear. For this reason, I went back through the text again and made a later revision in 2008. The text is up-to-date but some of the figures (graphs) are lacking the most recent information. As well, the bibliography does not contain all of the most recent books and articles on this subject.

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Mikhail Gorbachev

I HAVE OFTEN BEEN ASKED why, as an astrophysicist accustomed to describing the stars and galaxies, I have undertaken to write a book about the state of our planet.

The reason is that, beyond being a researcher in astrophysics, I live on the Earth, and I am a citizen of this world. I also have children, grandchildren, and friends who are dear to me. Our future on this planet is a matter of great concern. It took billions of years for life on Earth to produce the marvel that is the human brain. It's a fabulous cosmic odyssey that could very well founder by our own fault.

The litany of ecological disasters and threats to our biosphere is well documented, and we will be returning to it throughout this book. The list includes global warming; the thinning of the ozone layer; soil, air, and water pollution; the depletion of natural resources; the disappearance

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of forests and wetlands; the accelerated extinction of living species; and the insane accumulation of chemical and nuclear waste. Our planet is in bad shape.

History provides us with a long line of Cassandras and prophets of doom. The reader may very well ask: do the cries of alarm being raised today come from false prophets as well?

It is important, so as not to be confused with those harbingers of the apocalypse, that we stick closely to established facts, and monitor as accurately as possible the truth of what we say. The scientist's duty is to assess with a critical cast of mind the seriousness of the dangers facing us, and to be extremely cautious in presenting results and evidence for conclusions.

I will make much of what has been called the "precautionary principle."[1] Must we, in fact, wait for complete and irrefutable proof of danger before taking it seriously? If you see smoke in your kitchen, you are alarmed before you know for certain there is a fire.

Incidentally, we can confirm that alarmist predictions in the past, even when shown to be exaggerated, have often played a useful role. Advanced warnings have done much to reduce the scale of impending catastrophes.[2]

It's important to distinguish the fate of humanity from that of life as a whole. Life, we now know, is extraordinarily resilient. It will continue to adapt and to flourish as it has done for the last billion years in an astonishing variety of forms. But we humans are much more fragile. Our survival depends upon the future conditions of the planet's surface.

We are capable of making the planet unlivable for our descendants. We have embarked on a perilous experiment with our climate on a planetary scale. The effects are already visible, and we are monitoring those to come with some anxiety. No one can foresee when this experiment will stop, or what the biosphere will look like when it does.

Unlike a scientific researcher, we cannot simply stop the experiment

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midway if it turns bad. Nor can we close up the laboratory and go home. We are in the test tube, along with our children and grandchildren.

THE HUMAN CATACLYSM

A revealing comparison can be made between the current situation and the biological crisis that took place sixty-five million years ago.

At that time, a giant meteorite struck the Earth in Yucatán, a state in Mexico. The consequences of that collision were cataclysmic. The shock generated energy comparable to that of hundreds of millions of atomic bombs. There are excellent reasons to believe that this impact was responsible for the disappearance of the great saurians (such as the famous dinosaurs) as well as 50% of all living species.[3] The phenomenon was short-lived: a few seconds for the shock, a few decades of climatic and biological fallout. Happily for us, our distant ancestors, small tree-dwelling monkeys that one can find today in Madagascar, survived the catastrophe. Subsequently, radical changes took place in the evolution of life. Mammals, which had already existed for more than a hundred million years, proliferated enormously, bringing into the world primates, hominids, and Homo sapiens (ourselves).

Geologists call the period that preceded this event "the Cretaceous," and the period that followed, "the Tertiary." This chronological distinction derives from the discrepancies in the fossil record before and after that date. Geologists have identified five great episodes of biological extinction in the Earth's history, the most recent being that of the dinosaurs.[4]

Today, we are experiencing upheavals that risk being as grave as those in geological ages past. Which is why the term "sixth extinction" has been applied to the current crisis. This term, alas, seems perfectly justified. At the Bonn Convention on Biological Diversity (May 2008), experts estimated that the annual rate of species extinction today is a

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thousand times more rapid than before the industrial era, and that more than 30% of all species could disappear by 2050, with no guarantee that the trend will stop there. (See below, "Estimates of the rate and extent of the extinction of living species.")

The current crisis has many causes, and almost all of them relate more or less directly to human activity. These will be enumerated throughout the course of the book.

ESTIMATES OF THE RATE AND EXTENT OF THE EXTINCTION OF LIVING SPECIES

Robert May of Oxford University and President of the Royal Society, in a speech in November 2001 at the annual conference of the Society for Conservation Biology: "The rate of species extinction has accelerated over the last hundred years, to about a thousand times what it was before the arrival of humans."

E. O. Wilson, Harvard University (one of the most distinguished biologists of our time), in The Diversity of Life: "We estimate today that between 1 and 10% of species are eliminated each decade, or about 27,000 each year."

Michael Novacek, the American Museum of Natural History in New York: "It is not unrealistic to foresee that we will have exterminated half of all living species by the middle of the twenty-first century."

A 1998 survey indicated that 70% of biologists believe that we are in the middle of a massive wave of extinction. A third expect a 10 to 50% loss of species over the next thirty years.

According to the United Nations Environment Programme, close to 25% of mammals (1,130 species) and 12% of bird species are threatened with extinction.

Source: Scientific American, November 2001.

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VISIBLE SIGNS OF WARMING

One of the most unsettling climatic developments is the warming of the planet and the various weather disturbances it brings in its wake. The list of phenomena routinely cited in the press and on television, which leads us to affirm the reality of global warming, includes:

- The rapid shrinking of frozen surfaces on our planet.[5] The snow layer has diminished by 10% since the end of the 1960s, and at the same time, the period of freezing on lakes and rivers has shortened by two weeks on average. In the northern hemisphere, the duration of sea ice in spring and summer has been reduced by 15%.
- Submarines passing beneath the North Pole have observed a 40% thinning of the pack ice, while mammoth icebergs, as vast as a French county, are breaking loose in the Antarctic and drifting off to melt in the ocean. The facades of glaciers are retreating rapidly up mountainsides. Compare photographs of Chamonix in France at the beginning of the twentieth century with those of today. The melting of ice is a threat to many populated areas, especially in the Himalayas. The eternal snows of Kilimanjaro, so imposing as they look down on herds of elephants in Kenya, are melting away before our eyes, and may not last another twenty years.
- More spectacular still is the frequency of truly violent climatic events: floods, storms, and droughts. The number and cost of natural disasters across the globe has increased enormously. The annual count of floods and cyclones has multiplied five times between 1950 and today. The costs have risen both because of the growing frequency and seriousness of natural disasters and because more and more people tend to live in high-risk zones.

We should also take note of a phenomenon that all nature lovers have come to recognize in their gardens and in the woods: the adaptive

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response of living things to this rise in temperature. The return of migrating birds, the laying of eggs, and the first appearance of vegetation are occurring noticeably earlier. In the Mediterranean, the buds on leafy trees are opening sixteen days earlier, and the leaves are falling thirteen days later than fifty years ago.[6]

We must still determine the first causes of this warming. It could be argued that warming is due to natural phenomena and not human activity. Indeed, geologists have taught us that the Earth experienced a number of temperature variations in the past: a long succession of glacial periods and warm periods. We might ask the question: could this not be a phase in the millennial cycle?

The concerns about global warming began around 1980, when James Hansen of NASA, on the basis of computer-generated atmospheric models, concluded that the emission of CO_2 and other gases generated from the burning of oil, carbon, and natural gas were raising the world's temperature. This news caused great turmoil in the economic world. It was immediately contested by oil company engineers (especially those from Texas and Saudi Arabia), for whom climatic variations arose entirely from natural causes. Industry, in their opinion, played only a negligible role.

But the alarm had been sounded. The United Nations formed a commission, the Intergovernmental Panel on Climate Change (IPCC), to study the question. More than 2,500 experts from around the globe took part. Their reports were then reviewed by other scientists, and reviewed again at the time of the United Nations' plenary sessions.

In 1995, the IPCC very cautiously presented its preliminary conclusions in the following words: "The weight of evidence suggests a perceptible influence of human activity on the global climate." In February 2008, the IPCC went further: "There is a 90% probability that the warming of the last fifty years is due to human activity."[7]

It would be extremely unwise not to take these conclusions seriously.[8]

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Here, the scientific precautionary principle must be respected, especially given that the extent of warming is not easy to evaluate — the reason being that it is difficult to establish accurately the temperatures of the more distant past. However, a number of methods do intersect and indicate that the Earth's average temperature has increased by almost 1°C since the beginning of the twentieth century. The rate of growth has become especially rapid since 1990, and shows no signs of stabilizing.[9]

We have been sorcerers' apprentices. We have set the ball rolling, and it is only now that we are asking ourselves how we can stop it.

Fortunately, science can come to our aid thanks to computer modelling. Many scientific researchers, in particular those of the IPCC, are working on this. Once again, the answers are elusive because of the difficulties inherent in climatology — as we all know from weather reports.[10] The estimates for increases in the Earth's annual average temperature, according to scenarios of human behaviour, go from 1.5 to 5°C and greater for the end of the twenty-first century. According to many climatologists, the situation has already deteriorated to the point where, even if we succeeded in rapidly and effectively limiting the emissions of CO_2, it would take more than a century to halt global warming.

This indicates the seriousness of our situation: global warming could be disastrous for humankind. One might object: the Earth has known other warmings in the past. But what these earlier variations demonstrate is that a difference of only a few degrees is no small matter. On the contrary, during the last ice age, with a decrease of 5°C, the sea level went down by about 120 metres (one could walk from France to England). Canada and northern Europe were covered in glaciers several kilometres thick, like Greenland and the Antarctic today.

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THE DANGEROUS INTERPLAY OF CARBON DIOXIDE, WATER VAPOUR, AND METHANE

Global warming could extend far beyond the next century. In the first place, the emission of carbon dioxide could continue until fossil fuels, coal in particular, are depleted. There are still, now, abundant reserves. In the second place, a number of phenomena linked to other gases (called greenhouse gases — we will return to them in Chapter 1), such as water vapour and methane, could exacerbate the warming.

Here is the situation in brief. The increase in temperature hastens the evaporation of ocean water. The water vapour that is released from oceans, rivers, and lakes contributes, in turn, to raising the temperature, which accelerates the evaporation even more, in an ever-increasing cycle.

Even with carbon dioxide emissions and evaporation from oceans and lakes taken into consideration, rapid global warming will be accelerated by the appearance of the sleeping dragon under the polar snows, which would have been better left undisturbed: methane. Permafrost covers vast regions in the high latitudes — Siberia and Canada — where the subsoil is permanently frozen, as summer does not last long enough to melt it. Huge quantities of methane (see Chapter 1, Note 1) are trapped in the crystalline mesh of ice. Methane is a gas that has the capacity to heat up the atmosphere ten times more than CO_2.

Methane already represents more than 5% of the greenhouse effect, and its impact is rapidly growing. Freed by the accelerated melting of the permafrost due to warming, it could have a major influence, and, in concert with CO_2 and water vapour, speed up the process to the point where it reaches very high temperatures.

But we must reiterate that, given our limited knowledge of meteorological matters and our restricted powers of computation, we cannot, today, predict the global temperature that might be produced by these phenomena. Although it is possible that counter-effects could come into play that would reverse the trend,[11] one thing is clear: we are sailing

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through dangerous waters, and they may very likely become hotter and hotter.

The real problem is the speed with which these processes are taking place. That is the crux of our current dilemma. We will return to this topic often.

THREE SCENARIOS FOR CATASTROPHE

To illustrate our situation, imagine this story: a man is stricken with cancer. Underestimating the seriousness of his condition, he refuses to submit to the usual treatments. To persuade him, the doctor describes to him the catastrophic scenarios that could lie in wait if he does not allow himself to be attended to. He will then make his decision, fully aware of the possible consequences. Of course, nothing is certain. Sometimes cancers develop in unexpected ways and cure themselves spontaneously. Again, we are dealing with the precautionary principle.

We will take the same approach with our patient, the planet Earth, which is suffering from a high fever. The thermometers indicate that its temperature is climbing. Which raises some crucial questions: what temperature will the biosphere reach in the future? What will the effects be? Depending on the maximum temperature attained, we can foresee three different scenarios.

THE DESERT SCENARIO

This scenario applies to a world where, beyond the year 2100, the Earth's average annual temperature has climbed another ten degrees.

Deserts, already expanding rapidly, will increasingly encroach on arable land. We will witness a massive migration of fauna and flora towards the polar regions, where the temperature will remain livable. Only species adapted to desert climates (insects, resistant plants) will continue to survive in lower latitudes. The transition will likely be too rapid for most animals and plants to be able to adapt. Only extreme

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climate control will permit a few privileged humans to carry on.

In addition, the thermic expansion of water, associated with the melting of ice in Greenland and the Antarctic, could raise the sea level several metres, flooding coastal cities and large low-altitude continental expanses, reducing the amount of habitable land even more (*Figure 0.1*).

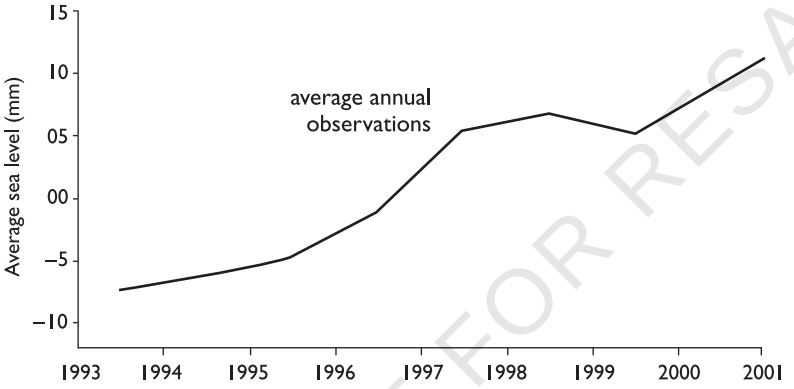

Figure 0.1. The increase in the average sea level between 1993 and 2001 (about 2 centimetres), as measured by the Topex-Poseidon satellite. This increase is due almost entirely to the expansion in the volume of water caused by climatic warming. The melting of continental ice is also a factor, but a very small one.

THE GEYSER SCENARIO

Now imagine that, under the synergistic influence of greenhouse gases, the Earth's average annual temperature were to rise dozens of degrees further. Let us say up to 60 or 70°C. Almost certainly, all multicellular organisms — animals and plants — would perish. Even insects. The proportion of species exterminated would exceed that of all previous extinctions.

There would be one notable exception: bacterial life. Its extraordinary robustness is one of the great discoveries of modern biology. "Extremophiles"[12] is the name we give to those varieties of bacteria that survive under stupefying conditions: the most acidic, alkaline, saline, the most

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intensely radioactive, and at temperatures approaching the boiling point (100°C) or the freezing point (0°C) of water.

The boiling water intermittently ejected by Icelandic geysers falls back into bluish ponds, where large colonies of blue algae flourish, possibly the first living beings that appeared on our planet. They give us a good picture of primitive life on Earth and its proliferation during the first three billion years of existence. This is the "Geyser Scenario."

Here, we find life on Earth as it may have existed prior to the appearance of the first multicellular organisms (plants and animals). Chronologically, it puts us back about a billion years in biological history. According to this hypothesis, human aggression will have accomplished what no other geological or astronomical activity has been able to do: return life to its bacterial, unicellular beginnings.

Of course, beginning from there, a whole new cosmic adventure could unfold. We can try to imagine it by drawing on our knowledge of the past. The new geological era would be characterized by the biological evolution of primitive cells, more or less analogous to those of a billion years ago. We could conceive that, in conformity with Darwin's schema, they would develop techniques for adaptation over the ages that would be increasingly complex and effective. By analogy with ancient history, unicellular living beings could again join together to form complex organisms, superficially different, no doubt, from those of earlier eras, but still acquiring similar attributes: sensory organs, breathing, digestive and reproductive systems, technical skills. And perhaps, one day, we could exclaim, "Well, well, mankind has come back!" After a long eclipse, we would be there again, and in the course of time we might even behave in such a way as to encounter the same problems we face today. Life on Earth took nearly a billion years to evolve from individual cells to the level of primates, but the sun has almost five billion years left in its cycle before it vaporizes the planets. On a cosmic scale, there would still be time to replay the same scenario.

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THE VENUS SCENARIO

The two scenarios already envisaged bring us to a third that would generate an even greater increase in temperature. Here, we must anticipate the worst. We are talking of average annual temperatures well above 100°C. Even the most robust extremophiles would be unable to withstand such extreme temperatures.

We will call this the "Venus Scenario." It is there before us when we admire the magnificent morning or evening star. But its brightness sends us a sombre message, a dramatic warning. Venus is sterile. Observed at close range by space probes, its surface is infernal. The temperature there is 460°C. It rains sulphuric acid.

However inhospitable the environment on Venus, it is Earth's twin to a large degree. The two planets' mass, their distance from the sun, and their quantity of carbon are not that different. But the composition of their atmosphere is radically dissimilar. Venus's atmosphere, composed of carbon dioxide, is responsible for this gigantic greenhouse effect, where no life, such as we know it, is possible.[13]

This is a nightmare scenario, and I would like to offer some reassurance: in the light of our present knowledge, it seems most unlikely. But given what little we know about how the factors involved interact, it would be imprudent to rule it out altogether. Remember that we have chosen, in our exploration, to look at the worst possible case. The Venus Scenario erases four billion years in the growth of cosmic complexity on our planet. We are left with the Earth such as it was in its first hundreds of millions of years, before the deposit of a cover of liquid, before the first molecular reactions that initiated the extraordinary, and still poorly understood, process that gave us the first living cells that dominated the planet for more than three billion years.

Since we are giving our imagination free rein, we can imagine that the process might start up again, and, after billions of years, bring forth life once more. It happened at least once. Why not again? Perhaps

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plants and animals would reappear. But by this time, the sun would be getting older, time would be limited.

These are three scenarios our sick planet could face if we do not do everything we can to arrest the increase in temperature of the Earth's atmosphere. All that, I repeat, is within the realm of the possible.

We have just exercised our powers of imagination. It's a precious faculty with which we have been endowed. It's possible that we might use it to avoid succumbing to a runaway greenhouse effect. I hope we will, and in fact, I believe we can, even if it's very hard to say how. We must use all our resources to stop this warming. We must act quickly if we want to give humanity its best chance to continue its extraordinary adventure on Earth.

This means painful choices and drastic measures. We must ask ourselves: are we prepared to forego the many advantages and comforts of modern life? What political party will be courageous enough to build into its program a massive reduction of automobile traffic or energy production? Can we imagine a reversal of our thrust towards ever more energy production? Can we, for our own good, call the retreat?

As history has shown, man always waits to be confronted with a catastrophe before drastically changing his attitude.

"To protect the environment costs a lot.
To do nothing will cost much more."
Kofi Annan

PUTTING THE BRAKES ON TEMPERATURE

We are facing a crucial question: what could stop a warming process that has already gathered considerable momentum thanks to human activity? There are two possibilities: one pessimistic, the other optimistic.

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We'll let the pessimist go first. Since the warming is primarily due to human activity, we may suppose that the disappearance of this species — or its considerable diminishment[14] — would stop the warming (although we cannot rule out the possibility of a snowballing that could continue for a long time). This simply means that we will have paid the price for the crisis and will be absent during the era to follow, like the dinosaurs after the fall of the meteorite in Mexico, sixty-five million years ago. The difference, however, is that they were responsible for nothing.

Nature, it is said, is unforgiving. No species is immune to extinction. Millions of species have been born, have thrived, and have disappeared from the planet since the beginning of life on Earth. Life goes on without them. It is a normal part of biological evolution on our planet.

The criterion for permanence is simple: those species that have established a harmonious relationship with their environment, with the ecosystem of which they are a part, survive. What is needed is a fair exchange: giving and receiving.

My favourite example is the tortoise. It has existed for three hundred million years, and is threatened by no one, other than humans.

Where harmony with the biosphere is concerned, as a species, we trail far behind. One might say with reason that the Earth is infested with human beings (much more lethal than sharks).

A healthy planet encounters a sick planet:
"What happened to you?"
"Don't ask! I've caught a bad illness called 'humanity!'"
"Don't worry, I've had it before. It cures itself. It'll go away."

To raise our spirits, I will now outline the optimistic solution. It's what we hope for with all our hearts, and it's what so many people are working towards today. It represents a global return to sanity, to a humankind that is at last responsible and resolved to put an end to the

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deterioration of its habitat, and in such a way that it does not eliminate itself.

Throughout this book, after having described as objectively as possible the state of the planet, we will try to indicate the progress that has already been made, and the various practical measures that could help us to achieve our goal.

The task will be long, arduous, costly, and full of pitfalls. Initiatives that appear worthwhile could fail to deliver the results we hoped for. We must navigate by eye, testing the wind, careful about what we do. Once again, we are heading into a very dangerous zone.

We can be encouraged by the fact that concrete results have already been obtained when scientists, business people, and governments have agreed to recognize a problem and have undertaken to resolve it on an international scale. Two examples: the hole in the ozone layer, and acid rain. Not that these problems have been solved completely (we will have more to say about them further on), but progress has been made. This tripartite agreement (scientists, industry, governments) is the precondition for planetary recuperation — without it, nothing will change. The goal of all environmental movements must be to broker such agreements as rapidly as possible.

We cannot ignore the fact that there are many who dispute the gravity of our situation.

Let us first recognize that different opinions must be aired in any scientific debate, especially if there are economic implications and costly initiatives proposed. It is also important to assess as objectively as possible the arguments being put forth.

The most important and the most active dissenting group was the Global Climate Coalition, which, over a period of ten years, brought together oil companies, and coal and energy producers from around the globe in an effort to minimize the gravity of the situation and to pin the

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blame on natural phenomena. However, after the reports of the IPCC, companies such as Shell, Amoco, and British Petroleum withdrew from the coalition, which has since collapsed.[15] Subsequently, companies such as DuPont, British Petroleum, Amoco, and Shell have invested in renewable energy, while Toyota in Japan has tried to go beyond the goals of the Kyoto Accord in reducing gas emissions.

Some people continue, as is their right, to deny the risks to the planet. In a book that received a great deal of media attention, Danish scientist, Bjørn Lomborg, (see Chapter 6, Note 7) asserts that, contrary to the alarmist discourse of the ecologists, humanity continues to make progress.

The progress Lomborg refers to is real. Economies are prospering all over the world. Democracy and social progress are increasingly gaining ground. The production of grains has increased considerably over the last half-century. The average lifespan is climbing. Urban atmospheric pollution is diminishing.

There are, however, some serious qualifications to be made. As we will see in Chapter 3, the production of food in the world has been stagnant or in decline for the last ten years, while, according to the predictions of demographers, the global population will not level off before the middle of the twenty-first century.

Many of the advances cited by Lomborg only affect rich countries. The average lifespan in the former Soviet Union is, in fact, falling, as it is in sub-Saharan Africa (see Chapter 6). Pollution in cities is being reduced in rich countries, but is growing rapidly in poor countries. Just take a walk in Delhi or Bangkok, and you will regret not wearing a gas mask. Have we the right, from the high ground of our own comfortable existence, to ignore four-fifths of the human population?

But the most important point is that most of these economic, social, and political advances have been made at the cost of a rapid deterioration of the environment, which may no longer be able to support them. Given the fact that global reserves are not limitless, the expression "lasting economic growth" is an absurdity. The improvement in the quality of life

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in poor countries is, in itself, excellent news. But the facts are clear. If the Chinese and Indians had as many cars per family as Americans and Europeans, the consumption of fuel and the emission of carbon dioxide would reach catastrophic proportions. Add to that the enormous disparity in the living conditions of different populations. Fewer than 15% of humans consume 80% of our natural resources. The number of human beings who live below the poverty line increases every year. We will have more to say about the threat this disparity poses to the biosphere's future. It may represent the greatest danger of all.

A book like Lomborg's, in my opinion, plays a very harmful role by encouraging inaction at a very crucial juncture, when large-scale mobilization is an absolute necessity.

Once again, it's not a question of playing the prophet of doom, but of alerting the public, and political leaders to the catastrophic risks we are running, as we continue to behave as though nothing serious were hanging over our heads. We must not harbour the illusion inherited from scientism that we will inevitably, in the future, find solutions to all the problems that we cause. When animal and plant species disappear, it is already too late. If we are one day faced with an uncontrollable acceleration of the greenhouse effect, it will also be too late to save the human species.

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