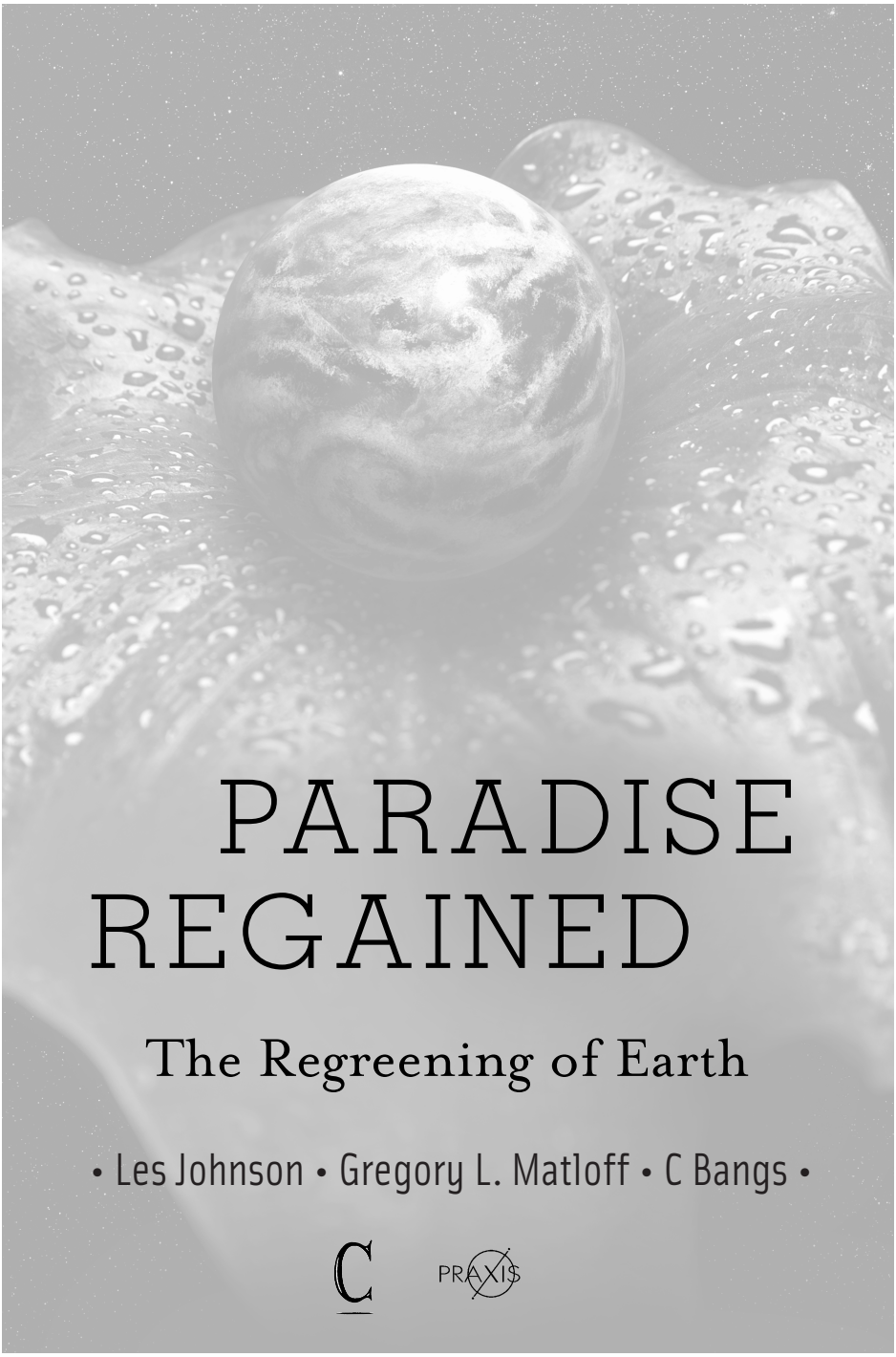
Paradise Regained



PARADISE REGAINED

The Regreening of Earth

• Les Johnson • Gregory L. Matloff • C Bangs •

C PRAXIS

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Dedicated to

My children, Carl and Leslie.
The future I am so dedicated to preserving belongs to them.
Les Johnson

Mother Nature, may she always be whole!
Gregory L. Matloff

The Earth and my parents, who bequeathed to me
their love for her.
C Bangs

Foreword

Gloom and doom sells. That salient point is made by the authors and, for me, is reinforced every time I sit down in front of my favorite cable news channel. Mass shooting at a high school in Iowa. The glaciers are still melting. Terrorists attack a hotel in Pakistan. The whales are going extinct. We hear about loose nukes, lunatics in power, corrupt politicians, child abuse, famines in Africa, tidal waves in Thailand. A woman in the Middle East is raped; then she is accused of immorality for allowing the attack to happen, and is murdered. Racial conflict shows up in Cambridge, MA. News arrives every day that the United States may sink under its accumulation of debt. And we all know the world is running out of oil.

Despite all this, the authors point that things have been worse. At the turn of the last century, people in the U.S. were, on average, not living much past forty. One thinks of the pre-Civil Rights era, of the Depression, of the nuclear confrontation between the superpowers over Cuba. I can recall, during those years, watching workers build an overpass on the Baltimore-Washington Expressway, and wondering why they bothered. At that time, an eventual all-out war seemed inevitable.

Paradise Regained has three authors. Gregory L. Matloff, a physicist at the New York City College of Technology; his wife, C Bangs, a Brooklyn artist; and NASA physicist Les Johnson.

Matloff is convinced that science and intelligence will eventually win out over the lunacy that has plagued mankind since Herodotus was writing history. He has published more than a hundred scientific papers, and is the author of, or collaborator on, seven other science books.

Bangs's work might be said to be inspired by starlight. She uses Gaia, goddesses, and the night sky to portray various aspects of the cosmos. Her conversations with her husband about life, death, and the universe provide much of the insight on display in her art.

Les Johnson has managed various in-space propulsion technology projects for NASA. He's worked on a tether experiment using Earth's

magnetic field for propulsion. And he has twice received NASA's Exceptional Achievement Medal.

In Paradise Regained, the authors recognize the severity of the problems that humanity faces, and they don't pretend that technological breakthroughs alone will be enough to save us. But it is clear that, without the technology, we are headed for a catastrophe.

And there is reason for optimism. After all, life is getting better. We live more comfortably than our grandparents did. It is now possible that African-American neighbors can show up in the neighborhood without unduly alarming those who really liked the nineteenth century. We now have the internet; we are showing signs of getting rid of tobacco, and medical science has come a long way. And we've developed a global sensitivity that we never really had before.

The authors suggest that the growing awareness that we share the same world, and that it has its limitations, began with those first photos of Earth taken from the moon, the pictures of the fragile blue world drifting through an endless sky. They're probably right. If the human race ever does really coalesce into a family, I suspect those pictures will be hanging near the front door of the family estate.

Will it ever happen? Bangs, Matloff, and Johnson think it will. And, in Paradise Regained, they lay out a plan to make it possible. If we choose to make the effort, to collaborate, to work together, here, they say, are the tools we will need. Here's how to deal with the inevitable energy shortages that are on the horizon, and do it in a way that does not wreck the ecosystem. They point out that we have a virtually infinite supply of clean energy available, compliments of the sun. All we need do is make the investment to harness it.

Here also is a technique for getting rid of the pollution caused by various manufacturing industries. And we might also want to take a long look at the dangers presented by near-Earth asteroids. A single rock, a mile or so in diameter, could put the lights out for all of us. Permanently. Most people shrug at the scenario. They would ask how many of them are there? The answer, unfortunately, is that they are numerous. And they are all over the place. Two weeks ago, as I write this, something very large crashed into Jupiter. We never saw it coming.

Then there are the issues of global warming. And conservation of resources. With world population at six billion and climbing, recycling aluminum cans, planting more trees, and turning the air conditioner down a notch won't get the job done. Won't come close. We're faced with serious problems, and eventually both will reach crisis stage.

Do the authors have a plan? You bet. It's not a solution we could manage today, because we don't have the technology yet. But there's time. If we act. If

we avoid our usual propensity of waiting until the flood waters are running into the valley. And that's the problem with the plan. It will require political will and advance planning. And maybe, most important of all, imagination.

I'd like very much to see a copy of Paradise Regained placed in the hands of leaders, and talk show hosts, around the world. The rest of us will be able to profit by it too.

Jack McDevitt
Nebula-winning author of *Time Travelers Never Die*

Acknowledgments

We would like to thank Ken Roy, Robert Kennedy, and David Fields for their contributing Chapter 14, Mitigating Global Warming. We are blessed to have such technically innovative thinkers as both colleagues and friends.

Thanks also to Mitzi Adams and Sam Lightfoot for providing their technical expertise in reviewing Chapters 4 and 6.

We appreciate our colleagues, friends, and students, who have been a constant source of inspiration.

I (Les Johnson) would like to thank Stuart and Dolores Peck for allowing me to use their spare room so that I could have a quiet place to write on Wednesday nights. I also appreciate the constant supply of ice cream they provided. A person could not have better in-laws!

Some of the chapter frontispieces utilize C Bangs's photographs of exhibits in the Hall of Human Evolution at the American Museum of Natural History in New York City.

Synopsis and Chapter Summaries

Synopsis

This book describes a scenario for the re-greening of planet Earth. The book begins with a description of what our planet was like before the advent of our modern civilization, followed by a summary of the effects of that civilization on the planet, culminating with a discussion of how we humans might use the resources of the solar system for terrestrial benefit, resulting in Earth becoming a place for a technologically advanced human civilization to live in synch, if not in harmony, with the environment that gave us birth.

Even if human population peaks at 15 billion or so, utilization of extraterrestrial resources can reduce the stress on the terrestrial ecosystem. If extraterrestrial energy sources can be tapped and certain polluting industries moved from Earth's surface to near-Earth space, a substantial fraction of humanity can ultimately enjoy the lifestyle of modern-day Americans, Europeans, and Japanese.

This book builds on the success of the Matloff, Johnson, and Bangs book, *Living Off the Land in Space* (New York: Springer-Copernicus, 2007). It is an updated successor to the popular book *The High Frontier* (New York: Morrow, 1977), authored by Prof. Gerard K. O'Neill of Princeton.

Paradise Regained is intended for a wide audience. Authors Johnson and Matloff contribute their technical expertise and writing experience. The chapter frontispiece art of artist Bangs adds a significant visual dimension to this proposed solution to our environmental dilemma.

Chapter Summaries

Introduction: Welcome to the Present

Chapter 1: Space Utilization: A Moral Imperative
It is in this chapter that we will put forth a moral concept on which this book is based. It is a concept that should have nearly universal appeal and should guide much of our decision making regarding both space and environmental policies. Simply stated, life is good. The converse is also a moral assertion: that which leads to non-life is evil. Those who seek to preserve life, human and nonhuman, are acting in a morally superior manner compared to those who seek to diminish or harm life. We believe the moral decision that life on Earth is good drives those in the modern environmental movement to their activism. It is this same moral decision that motivates many space enthusiasts, activists, and professionals. We discuss why space industrialization and utilization is a viable, long-term, moral solution to our environmental problems.

Part I: Mythical Paradise

In this section we describe the formation and resources of the solar system and the ecological state of Earth before humans.

Chapter 2: Fire: Formation of Earth and the Solar System
This chapter summarizes current theories regarding the formation of the sun and the solar system. Particular emphasis is placed on planetary formation and the composition of the asteroids and comets. (This information is referenced in later chapters as we discuss how these resources might be used for supporting our future technological needs.)

Chapter 3: Earth Before Man: Utopia or Nightmare?
In the infant solar system, many comet-like bodies drifted through the inner solar system. Over time, comet impacts increased infant Earth's inventory of water vapor. As the planet cooled, this material condensed to the liquid state and Earth's oceans were born. According to current theories, the oceans were incubators for early life. Life emerged from these oceans to begin colonizing Earth's land surface. For billions of years, life evolved and diversified on planet Earth. Starting with single-cell bacteria, algae, and protozoa, multicelled organisms developed and the world they created was one of cold-blooded survival of the fittest. Without sentience, there was no concept of love, justice, or caring for those that are ill or weak, and certainly no concept of art, music, mathematics, or literature. Is this "pristine" Earth a

viable model upon which we should base our environmental policies so as to re-create it?

Part II: Paradise Lost?

In this section we describe the environmental challenges facing humanity and describe why conservation and Earth-based alternative technologies will not be sufficient to avoid widespread ecological disaster—or the ultimate collapse of our technological civilization.

Chapter 4: The Environmental Dilemma: Progress or Collapse?

The second law of thermodynamics tells us that no energy conversion process is 100 percent efficient. There is a corollary to real-world engineering processes; no matter how hard we try, we will always have losses that will keep us from recycling with 100 percent efficiency. As demand grows and the supply of raw materials inevitably dwindles, recycling will become more essential, but in the long term, it, too, will fail to meet our needs. We will simply run out of resources. Long before that time, the pollution from a burgeoning materialistic (and prosperous) society will strain the ability of planet Earth to cleanse itself and we will run the risk of extinction from environmental degradation. The crisis may not be realized until 50 years from now or until 500 years from now—but it will happen. This chapter summarizes the challenges facing our civilization and our planet and asks the question, Do we want continued growth and progress, or collapse? It is in this chapter that we offer a potential solution to these problems through the development of space.

Chapter 5: Exploding Population

This chapter traces human population growth throughout history and ties it to the fraction of the species that today lives in relative prosperity due to their reaping the benefits of being part of a modern technological civilization. Past theories of population growth, forecasts of population collapse, and how we have continued to find technological paths to avoid such collapse are discussed.

Chapter 6: Climate Change

Putting aside the issue of whether or not the observed changes in the global climate are man-made, it is clear that our civilization still faces a tremendous challenge in dealing with observed and predicted changes in Earth's climate. For example, if the polar icecaps melt, then what impact will rising sea levels have on our civilization and economies? The predicted effects of climate change are outlined in this chapter.

Chapter 7: Vanishing Life
Planet Earth as a place for life is in jeopardy. Expanding human population, combined with climate change, is straining the sustainability of the few remaining habitats for wild life. Recent studies show that a distinct species of plant or animal becomes extinct approximately every 20 minutes; it is therefore conceivable that only our pets, food animals, and other domesticated species will survive the onslaught. We are poisoning our nest and killing, to the point of extinction, many species without malice of forethought, but by their misfortune of being in the way of our progress. This chapter provides a snapshot of the problem and discusses what experts in the field are predicting for the years to come.

Chapter 8: Diminishing Energy
The world's economic growth is driving an ever-increasing need for energy. Current methods of producing power are generally not environmentally friendly, and those that are green are often politically unacceptable to populations near where they are best implemented. This chapter discusses the recent history of energy production, various methods by which power is currently produced, and the environmental impacts of each. Specific technologies to be discussed include fission power, fusion power, coal, oil, natural gas, biofuels, wind power, and terrestrial solar power generation.

Chapter 9: Humans Before the Industrial Age: A Desirable Ecological Goal?
A common myth in popular culture is that we need to enact environmental policies that will return Earth to the near-pristine state of preindustrial human civilization. While this goal for planet Earth may be laudable, it is hardly an acceptable future for humanity. Modern civilization provides a quality of life that is vastly superior to that of our ancestors and it is doubtful that most of humanity will aspire to return to significantly shorter life spans full of rampant disease, poverty, and social inequity. In this chapter we discuss the lives of the common person in preindustrial society and assert that today's quality of life is morally superior despite the ecological consequences, considering that something must be done to prevent our hard-won societal progress from being lost as a result of our lack of good stewardship of Earth.

Part III: Paradise Regained
In this section we describe how the development of space and its resources not only can avert environmental disaster, but also can provide the basis for continued technological and societal progress.

Chapter 10: Raw Materials from Space
Space is not empty. Rather, it is populated with large rocky and gaseous bodies called planets, and millions of smaller bodies composed of rock and water ice (asteroids and comets). These smaller bodies contain many of the raw materials needed for our industrial society: metals, carbon compounds, silicon, and sometimes water. It is possible not only to mine them for these resources, but also to divert them to Earth for easier access. This chapter describes the resources of the solar system, referencing them against our projected industrial needs, and how we might use them to feed our industry once terrestrial sources become depleted or inaccessible.

Chapter 11: Power from the Sun
Sunlight reaching Earth contains 1368 watts of power per square meter. Assuming only a modest increase in sunlight-to-electricity conversion efficiency, it is conceivable that large solar array "farms" in Earth orbit could collect gigawatts of power and beam it back to the terrestrial power grid in an environmentally responsible way. The idea is not new, but the technologies that might make it possible are rapidly advancing. This chapter describes the concepts envisioned for space-based power generation systems and how they will work synergistically with Earth-based conservation to result in plentiful energy for the world's growing needs.

Chapter 12: Environmental Monitoring from Space
Earth orbit provides an unparalleled vantage point for monitoring global environmental change. The current generation of space satellites is providing environmental scientists and policy makers with nearly real-time information regarding global atmospheric and sea temperatures, sea levels, rainfall rates, atmospheric trace gas composition and variability, as well as numerous other indicators. In this chapter we discuss current, planned, and potential future capabilities for monitoring Earth's weather and climate from space.

Chapter 13: Protecting Earth
From the asteroid impact that is thought to have made the dinosaurs extinct 65 million years ago to the rock that hit Tunguska, Siberia, in 1908 with the force of a 20-megaton nuclear weapon, Earth is in the shooting gallery and it is only a matter of time before we are impacted again. (The Tunguska event was about 1000 times more powerful than the atomic bomb dropped on Hiroshima, Japan.) Fortunately, we have the ability to go into space and divert any potential threats to the planet—a capability the dinosaurs did not have. This chapter discusses the impact threat, provides an overview of past

impact events, and discusses the options we have for averting similar disasters by detecting, characterizing, and diverting any objects that might impact Earth.

Chapter 14: Mitigating Global Warming
According to the International Energy Agency, it is projected that carbon-dioxide emissions will more than double by the year 2050, with developing countries accounting for almost 70 percent of the increase. Even with draconian emission reductions on the part of the industrialized world, global CO_2 emissions will continue to grow at an alarming rate and, if current theories are true, the world will continue to get hotter. Several ideas have recently been proposed for mitigating this global temperature rise by blocking a small amount of the sunlight reaching Earth using space-based filters or sunshades located at one of the Earth/sun Lagrange points. These approaches are discussed in the context of how they might be used in conjunction with conservation and slowing the growth of greenhouse gas emissions on Earth to reduce the global temperatures to pre-20th-century levels.

Chapter 15: Settling the Solar System
To thrive on Earth in large numbers, humans must experiment with various forms of renewable energy and lifestyles that are less degrading of the environment. Many of these techniques are similar or identical to those that will be required to settle nearby regions of the solar system. How might we use solar energy and closed ecological systems in space to plant self-sufficient human habitats on the moon, on Mars, or in free space?

Chapter 16: Paradise Regained: An Optimistic Future
The marriage of environmental action and space technology implementation can achieve what might otherwise be impossible—the return of Earth to being a planet for life (all life, not just our species) with an ever-increasing standard of living and quality of life for all its inhabitants. Space-based industries can produce many of our industrial products without "fouling the nest." Solar power satellites can augment terrestrial sources, obviating the need for more fossil and nuclear-fueled power plants. Asteroids can be diverted to avert global disaster and to provide nearly infinite resources. And Earth can once again be a place for life. This chapter summarizes how space technologies can work synergistically with conservation, recycling, and planned growth to build a prosperous and sustainable future for all of humanity.

Author Biographies

Les Johnson

Les Johnson is the deputy manager of NASA's Advanced Concepts Office at the George C. Marshall Space Flight Center in Huntsville, Alabama. Previously, he managed NASA's In-Space Propulsion Technology Project, developing advanced technologies such as solar sails and aerocapture for future space science missions. From 1996 through 2003 Johnson was the principal investigator for the ProSEDS tether propulsion experiment. In addition to his NASA credentials, Johnson also is an inventor. He holds three patents, was twice the recipient of NASA's Exceptional Achievement Medal, and is the author of numerous technical publications, coauthor of two mass-market popular science books, and has consulted on various novels and a major motion picture.

Gregory L. Matloff

With an M.S. in astronautical engineering and a Ph.D. in applied science (both from New York University), Greg Matloff has published or delivered about one hundred research papers related to atmospheric physics, space exploration, or space science, and has authored or coauthored seven books and many popular articles. As well as teaching physics at New York City College of Technology, he consults for NASA Marshall Space Flight Center, is a corresponding member of the International Academy of Astronautics, a fellow of the British Interplanetary Society, and a Hayden Associate at the American Museum of Natural History. With his wife C Bangs, he resides in Brooklyn, New York.

C Bangs

With a B.F.A. from University of the Arts and an M.F.A. from Pratt Institute in painting and sculpture, C Bangs has exhibited her art in museums and galleries throughout the United States, South America, Europe, and Australia. She has created the chapter frontispiece art for the books authored by her husband, Greg Matloff. Her work has appeared in the

Journal of the British Interplanetary Society, *Analog: Science Fact and Fiction,* and *Zenit*. She worked under a grant at NASA Marshall Space Flight Center and then as a NASA faculty fellow for three sequential summers. Her art is included in numerous public and private collections.

Introduction: Welcome to the Present

I know a bank where the wild thyme blows,
Where oxlips and the nodding violet grows;
Quite over-canopied with luscious woodbane,
With sweet musk-roses and with eglantine

William Shakespeare, *A Midsummer Night's Dream*

If you are reading this book, you are most likely a member of the most privileged generation in the history of humanity. You have a roof over your head—a vast improvement over the lot of many of our ancestors and a significant number of humans today. You have access to quality health care facilities and can count on between 70 and 80 good years of life.

Clean water is yours at the twist of a knob. And food—as healthful or exotic as you might desire—is available a short walk, subway ride, or drive from your front door. Your great-grandparents might have sacrificed a great deal for these advantages alone.

Education, although not universal, is widespread. In all likelihood, you have a moderately creative and financially rewarding professional life—also a great rarity before about 1950. If you push a button, entertainment and information from the world over can flood your consciousness. You can even remain connected to this planet-wide information network as you walk in a park, cook your dinner, or ride in a car.

But problems loom on your, and our, horizon—problems that threaten to swamp our glorious era. The world's population continues to expand. And surprisingly to some (but not to us), the burgeoning populations of Asia, Africa, and South America desire the same advantages enjoyed for many years by North Americans, Europeans, Japanese, and Australians.

Can contemporary civilization provide for billions more humans living well? Where will the energy come from? How do we deal with the pollution? Will carbon dioxide emissions and other human-produced greenhouse gases evoke long-lasting climate change that will increase global temperatures, raise sea levels, and swamp coastal lands?

Years ago, as our ancestors began to emerge in the park-like savannah of

central Africa, a response developed to the problem of environmental degradation. When your local environment was exhausted, move! This worked well as hunter-gatherers spread around the globe and civilizations developed and spread. The world is littered with the ruins of once-great cities surrounded by degraded environments.

But today there is nowhere to flee. Civilized humans are everywhere on Earth. Early science-fiction authors hoped for benign climates on neighboring worlds, but none of these worlds could sustain more than a tiny fraction of the human population, and that at great expense. Even if people were genetically modified with gills to live in the oceans, this would be a mere stopgap measure; the oceans are not immune to human pollution.

Conservation, limiting growth, and recycling can provide some relief, but any such relief will almost certainly be only temporary. With the rest of the world's economies growing into variations of our materialistic one, it is only a matter of time before we simply run out of resources, energy, and places to store our waste. This does not mean we should not conserve, limit growth, and recycle! On the contrary, these measures are essential to the survival of our civilization and, potentially, our species. They are simply insufficient to resolve the core issue we face—that Earth cannot by itself indefinitely sustain a worldwide population of consumers. It is impossible to recycle with 100 percent efficiency, to mandate no growth, or to conserve our way into prosperity.

It was a bitter day in December 1968 when humans in general became aware of their kinship as riders on a fragile, living Earth. From a quarter million miles away, the crew of Apollo 8 pointed their cameras homeward after they had safely settled into humanity's first close flyby of the moon.

The view of the desolate moon was striking on our television screens, and the astronauts' scripted reading from Genesis was stirring. But it was the shimmering, living, marble-sized Earth, hanging in stark contrast above the lunar horizon that would profoundly alter our view of our world and ourselves.

Living worlds are fragile and delicate. And space is very, very large. This lesson would be repeated and amplified in 1990, when, on the edge of the galactic void, the cameras of Voyager 1 were focused back on our planet. From its multi-billion-mile vantage point, Voyager imaged Earth as a pale, blue dot almost lost in the glare of the distant sun. Earth is a seemingly unique abode for life in an otherwise empty and apparently lifeless expanse of nothingness.

So as you escape our increasingly urbanized world to stroll through your local park, botanical garden, or forest, and gain spiritual sustenance from your temporary immersion in this sanitized (predator-free) version of our