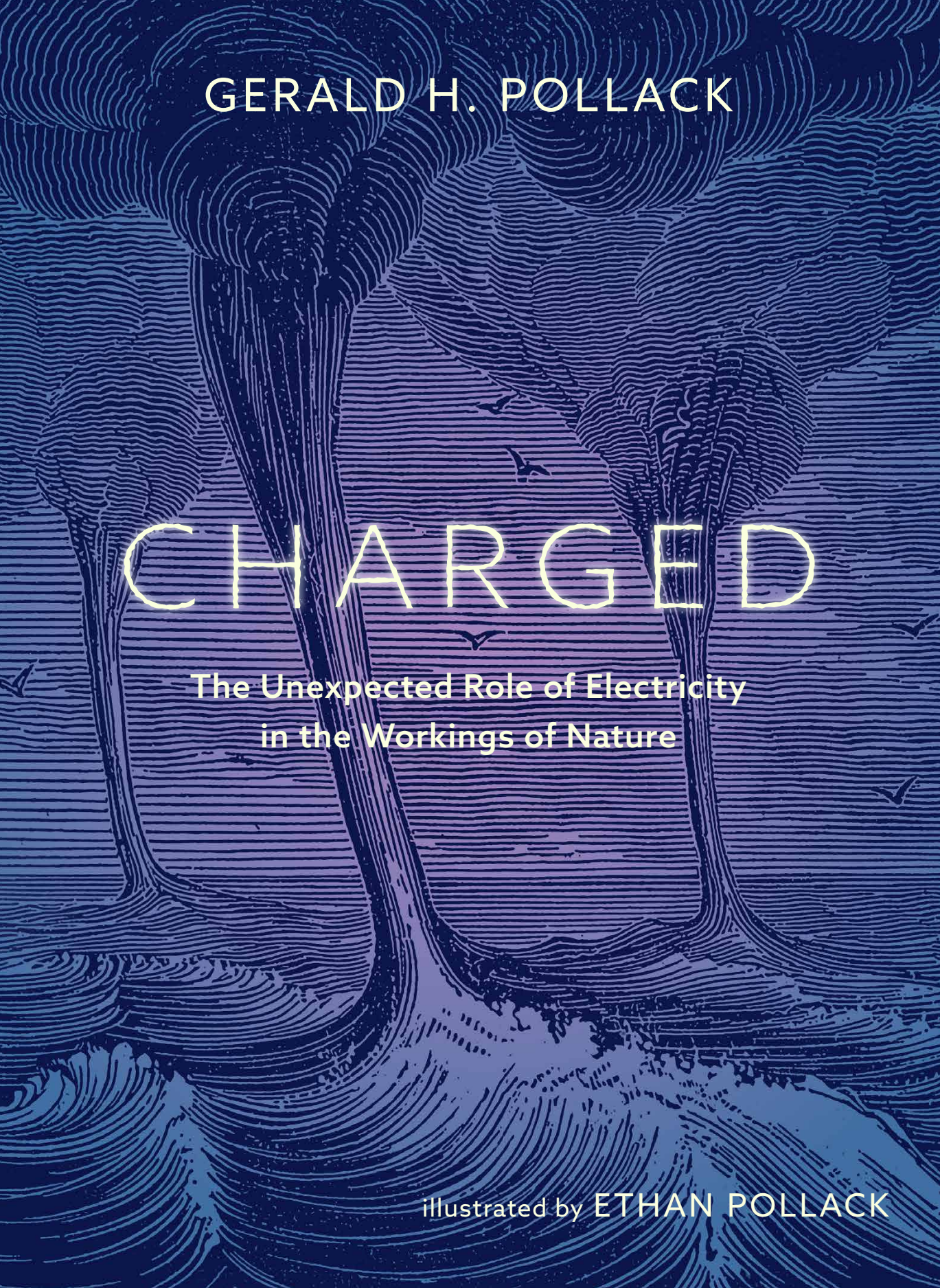




GERALD H. POLLACK

CHARGED

The Unexpected Role of Electricity
in the Workings of Nature

illustrated by ETHAN POLLACK



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Written by Gerald Pollack

Illustrated by Ethan Pollack

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*To the memory of Emily Freedman,
my life-partner for a quarter century,
who unselfishly supported all aspects
of this work and lent gentle words of
encouragement along the way.*

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Preface

Imagine a sixth-grade science class — maybe even yours.

The teacher begins by showing the students a hand-drawn sketch. The sketch depicts the ancients, our long-forgotten ancestors, staring in awe at a vast field of erupting volcanoes. You can imagine the scene. With a superimposed background of dark, ominous-looking clouds spewing terrible flashes of lightning, what else could those ancients think but that “these awesome phenomena must be created by some kind of god.” Poor, unfortunate ancients, laments the teacher. They know not what they think.

Then comes the inevitable rescue: “It was not until the advent of modern science that we came to understand these things.”

But do we really understand them? Do modern scientific paradigms improve our grasp of everyday phenomena? Do they help us understand why clouds float? Or why spiders can sometimes fly? Or why the earth relentlessly turns on its axis?

This book seeks answers to such questions. It does so by identifying fresh beginnings — simple scientific foundations with appreciable explanatory power. It acknowledges that phenomena not readily understandable to early humans might remain obscure even to people of today, *i.e.*, that at least some prevailing paradigms might be missing that simple, reassuring, ring of truth. To be clear, I don’t profess *a priori* that most current paradigms are necessarily misguided; that would be arrogant. But the complexity of many

of those paradigms does lead us to wonder whether simpler foundational concepts might be worthy of exploration.

In considering the prevailing paradigms, we immediately think of the towering figures of science who brought us there: Albert Einstein, Max Planck, Richard Feynman, and others. Even though most of us might not fully grasp the entirety of their theoretical constructs, we defer to them almost reverentially. We accept what they profess, even if we don't get it all. Hence, a question to you, the reader: Have their arguably arcane theories brought you to a satisfying understanding of the workings of nature? Or, have you reluctantly concluded that the fundamentals lie beyond your comprehension, leaving ownership of ground truth to those scientific sentinels? Have modern scientific deities replaced those early imagined gods?

For many, today's science can seem practically impenetrable. We may easily follow the superficial descriptions, only to lose our way when trying to comprehend the detailed underpinnings. For example, some of you might have heard about the Higgs boson (sounding suspiciously like the latest cool dance). Touted as a fundamental particle of nature, confirmation of this so-called "God" particle had seemed significant enough to earn Peter Higgs, an English theorist, the 2013 Nobel prize. But what does the Higgs boson mean? How can we understand the implications of its existence for our daily lives? If you feel at a loss over how such sub-atomic particles fit into any context relevant to your world, you're not alone. We remain collectively bewildered, much as we imagine our distant ancestors.

Lacking comprehension of many of the foundational underpinnings of natural science, we can easily feel helpless. We don't know what to think or do about the critical issues that now plague our society. You know the issues: pollution, global warming, electromagnetic smog, chronic disease, and others. Absent any intuitive grasp of first principles, we're forced to rely on the presumed wisdom of those scientific "experts" out there. Yet, the problems grow progressively more serious with each passing year. "Expert wisdom" has thus far failed to help solve our problems.

Thus we ask: How much responsibility lies in the increasing complexity of today's scientific foundations? Have we progressed as far from the ancients as we'd like to think?

Have Scientific Principles Always Been So Obscure?

Science has not always been so daunting. Beginning six centuries ago, the world's pre-eminent scientific philosophers had continually professed the importance of *simplicity* (or ontological parsimony). Newton set a prominent example. Had that temperamental soul managed to develop a sense of humor, he might have found occasion to express his position by invoking the principle now known as KISS — “Keep it simple, stupid!”

In fact, Newton went on to formalize the principle of scientific simplicity. He knew well of the philosophical principle set forth earlier by the 14th century English friar William of Ockham (sometimes spelled “Occam”). Occam asserted that, “It is useless to do with more what can be done with less.” In other words, keep your arguments simple. Newton built on that precept. He extended Occam's principle to the realm of science, arguing (in language fashionable at that time), “We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.” True, and sufficient — that's it. Out of the mouth of Newton.

Today, we call that principle “Occam's razor.” We might better call it “Newton's razor,” or even “Aristotle's razor” for his similar idea, expressed two millennia ago: “Nature operates in the shortest way possible.”

What's meant by “short”? Or “simple”? How do those concepts help you understand the world around you, or even exploit that understanding for creating a kinder, gentler, more accessible world?

The terms “short” and “simple” mean adhering to a logical cause-and-effect sequence — *A causes B; B causes C, etc.* Consider, for example, the explanation for the common whistling teapot. Applying heat to water in a teapot causes the water to boil; boiling water creates steam; steam in a closed vessel produces pressure, which forces the vapor to flow through a narrow nozzle. Flow through that narrow nozzle creates vibration, which your ears detect, and your brain interprets as the familiar whistle. Simple cause-and-effect linkages create an easily grasped logical progression. We can fathom those linkages without very much difficulty; each one is short, and simple.

Alternative scenarios may lack any such straightforward logic. Consider the following (admittedly silly) option: When water boils, sound comes from

gremlins lodged in the water. Annoyed by heat, those gremlins spring to life. As the water begins boiling, vibrational forces cause the gremlins to experience pain. They scramble to escape, screaming as they pass through the narrow nozzle. We hear that screaming as a whistle.

It goes without saying that this scenario will strike you as preposterous. But why? We reject the hypothesis not only because of the absence of a clear, logical sequence, but also from the unfamiliar notion of observable gremlins scrambling about. How does the very existence of those gremlins link to our life's experience? Why should those creatures preferentially settle in water? What mechanism endows them with the capacity to feel pain? And, if the gremlins' departure from the kettle occurs contemporaneously with the kettle's diminishing water level, might that imply that gremlins could in fact be *made* of water? Ouch!

Unanswered "how" and "why" questions leave us feeling uneasy. Even if we had imagination enough to consider a gremlin-centered reality, we sense that the required sequence of events will prove so cumbersome as to make nonsense of that explanation. The correct explanation, we intuitively feel, is likely to be a lot simpler.

What we intuitively sense was formalized by Occam and others after him: The most likely option has the fewest missing links in the chain of logic. That's what we mean by simplicity. Simplicity, in turn, implies elegance — a theme that Mother Nature likely employs in good measure. We are ineffably attracted to simple, elegant explanations. They carry the ring of truth.

Of course, simplicity need not *necessarily* equate with truth; no assurances exist that the simplest explanation will always turn out to be the correct one. Nevertheless, the pursuit of simplicity offers hope that science could, after all, make the workings of our universe understandable even to mere mortals like ourselves. Simplicity democratizes science. It opens the possibility that nature's first principles might be universally accessible.

Has Simplicity Vanished from the Scientific Scene?

The principle of simplicity seems so sensible that you may well wonder why I bother to dwell on its origins.

Oddly, this principle has practically disappeared from the contemporary scientific scene. My academic colleagues often revel in presenting their work

as complex — as though the ability to sort through intricate details places them in an esteemed position. The trend toward complexity may have begun a century ago with a statement famously attributed to Einstein: “*Everything should be made as simple as possible, but not simpler.*” Einstein understood the virtue of simplicity; yet, seeing evidence for such counter-intuitive phenomena as relativity, he had to admit that science might prove not so simple after all. He began harboring some doubts.

With each passing decade, simplicity has progressively given way to complexity. Recently, seeking information on the emission of beta particles, I went to the handiest source — Wikipedia (the free online encyclopedia). Here’s what I found: “This process is mediated by the weak interaction. The neutron turns into a proton through the emission of a virtual W^- boson. At the quark level, W^- emission turns a down-type quark into an up-type quark, turning a neutron (one up quark and two down quarks) into a proton (two up quarks and one down quark). The virtual W^- boson then decays into an electron and an antineutrino.”

Atomic physicists likely have no problem with this explanation, but God help the rest of us poor souls. It’s a foreign language — yet, conspicuously found in an encyclopedia designed for common understanding. Is such complexity really necessary for the description of a simple particle? Perhaps. But, must we then conclude that Occam’s razor has begun losing its edge?

My physicist friends assure me that science has *not* gone astray — merely that Occam’s razor has become as outdated as the steam engine. Physics, they claim, *is* non-intuitive. That notion gains grand support from Richard Feynman, the late 20th century’s preeminent physicist. In the introduction to his book on quantum electrodynamics, *QED*, Feynman reassures the reader about their prospective immersion into the complex material to follow: “It is my task to convince you not to turn away because you don’t understand it. You see, my physics students don’t understand it either. That’s because I don’t understand it. Nobody does.”

Was Feynman’s provocative statement designed merely to humor his colleagues? His charm was definitely endearing to those who knew the man. Just read his book, “*Surely You’re Joking, Mr. Feynman!*”, and you’ll see why. It was practically impossible to not love this captivating guy. I, myself, succumbed. I still cherish the man’s memory, relishing the elegantly simple way he could explain so many difficult concepts in physics. With regard to

his own most notable scientific contribution, however, one might wonder: Were those introductory words merely offered as a readership draw? Or, did Feynman feel constrained to admit that his seemingly monumental contribution was beset with daunting complexity?

Does nature really operate in a way that perplexes even the most brilliant of minds? Niels Bohr, who gave us the original planetary model of the atom, thought otherwise. He believed that, if a principle had genuine merit, you could explain it to your grandmother. (Few grandmothers were scientists in Bohr's day.) But today, we have come to accept that scientific fundamentals are not necessarily accessible to non-experts, let alone to their grandmothers.

Given this increasingly pervasive complexity, I've come to believe that the scientific enterprise may have lost its way. We think of the enterprise as ancient, and hence by now well developed. Indeed, judging from the written record you might conclude that we've progressed from *NO* science understanding to *SOME* science understanding. But does that necessarily mean we have *THE* science understanding? Scientific practice generally assumes not: It operates formally by challenging prevailing theories that seem incomplete, or at odds with experimental observation; it then attempts to replace them using a minimum set of postulates to approach natural truths. Most of current science, I'm convinced, fails to operate in that mode.

Nevertheless, much of science still seems young and enthusiastic, like a child excited to learn to ride a bicycle. Children may stumble many times before finally getting the hang of it. Science, likewise, seems to me to be functioning in a stumbling mode. Yet, the youthful exuberance of many engaged in the scientific enterprise cannot help but motivate fresh approaches for seeking out reality. Many scientists and non-scientists alike hunger for fundamental scientific truths. In our hearts and minds, we crave firm anchors to reality.

I'm full of hope that the flowers of scientific youth may blossom into something meaningful, enduring, and perhaps even beautiful.

Restoring Occam?

In seeking simplicity, we need to recognize that even the simple can sometimes become complex when one probes deeply enough. Lying beneath an explanation that might conform to Occam's razor sit questions that can

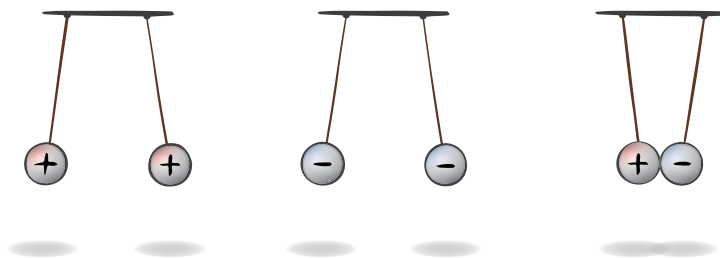
become vexing to answer. For example, the sun supplies much of the earth's energy, but how did the sun come to acquire that deliverable energy? I'm not sure the answer will be as simple as we might hope. Simplicity may have its limits. Notwithstanding, we begin with the presumption that a search for simple foundational concepts may provide the keys to the kingdom.

This book begins by recognizing a critical problem with the currently accepted scientific models: anomalies. Anomalies are observations brushed aside because they don't fit into a prevailing paradigm. But that raises a question: If the paradigm is adequate, then why shouldn't those observations fit?

Once I realized that many of the dominant paradigms of modern science came with well-recognized anomalies, I began feeling impelled to search for more reliable foundational truths and rebuild from there. Matters unclear should become clear. In that pursuit, I soon realized that anomalies can serve as gifts: They offer points of focus that need to be reconciled, for without reconciliation there can be no real progress. This book represents my best effort to build an understandable model of our natural environment free of obvious anomalies — at least anomalies obvious to me.

As I began proceeding along that course, I soon noticed the same feature appearing again and again: electric charge. As you will soon see, I came to appreciate that even small amounts of positive or negative charge can produce stunning forces, easily capable of driving diverse natural processes. This revelation spurred me into action, for I came to realize that charge forces — attractions and repulsions — could lead to simple, powerful hypotheses of the sort that Occam might have anticipated.

Essentially, I began to see that much of nature might prove directly interpretable in terms of the interplay of positive and negative charges. This seemed exciting and powerful — like knocking on the mother of all doors.



The Book That Follows

Perusing the Table of Contents can offer a glimpse of the diverse areas of science that this book explores. Those areas range from the nature of gravitation to the genesis of weather. I also touch on subjects of more common interest, such as how birds fly and how fish swim. And very much more.

Current science offers explanations for all those phenomena. Often, however, those explanations barely get us past the first round of questions. Yes, gravitation arises from the attraction of masses. But what mechanism *causes* those masses to attract? And more: Everyone knows that birds fly by flapping their wings. But what about those birds that don't commonly flap — how can they stay aloft? Another conundrum: Dark clouds may release rainfall; but not always. By what wisdom do those clouds decide whether or not to oblige us to open our umbrellas? How do they figure it out?

In the material that follows, I hope to appeal to common sense. My goal is to move us toward fundamental ideas that integrate us to reality instead of isolating us from it. The ideas should resonate in our hearts as truth, more powerfully than the bits and pieces of science deemed compulsory to represent reality.

In this pursuit, I do not hold back. If we are asked to blindly accept concepts lacking an accessible foundation of first principles, I speak up. If the emperor has no clothes, I say so.

The book is written for any reader. An advanced education is not necessary — I have done my reasonable best to keep the presentation straightforward. Since so much reference material can be found on the Internet (exercising due caution), I streamlined the text by omitting references to easily accessible information. On the other hand, when facts seemed unexpected or crucial for an argument, the relevant references have been included.

I recognize that colleagues steeped in their respective fields will likely come down hard on some of the proposed explanations, for few of us welcome challenges to our firmly held belief systems. History teaches us that only rarely do challengers escape the wrath of the fields' elders. No exception is anticipated here. After reading what follows, those colleagues may decide whether my efforts have provided some modicum of reassurance or have merely muddied the waters. I hope those colleagues will appreciate that this effort is driven solely by a compulsion to understand nature at its

core, a pursuit that cannot always be accomplished without a substantial dose of disruptive thinking.

Like any scientist with even a modicum of humility, I don't regard what follows as a statement of ground truth. As new evidence comes my way, I find myself continually refining my views. In that spirit, the ideas presented here are offered for rent, rather than for long-term purchase. My intent is to use electric charge as a vehicle to illustrate that we may be ripe for a return to simplification, a return to the deepest roots, with a new path forward.

I have nevertheless attempted to build an edifice of understanding based on simple observations and straightforward logic. While hoping to hone Occam's razor, my greater aspiration is to catalyze readers to question, and even reconsider, aspects of the scientific *status quo* that make little sense to them.

In so doing, I hope to inspire a more fruitful approach to understanding how the world works.

GHP

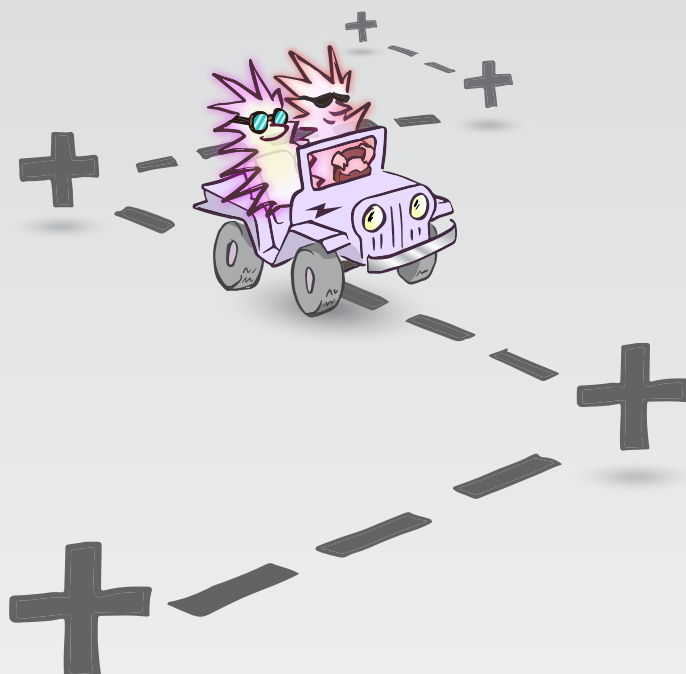
Seattle, WA, December, 2024

*It ain't what you don't know that gets you into trouble.
It's what you know for sure that just ain't so.*

— Mark Twain

Science is the belief in the ignorance of the experts.

— Richard Feynman



A ROADMAP

Questions You Might Never Have Thought to Ask

This Roadmap will help orient you to the route that this book will follow. Please consider it as “Chapter Zero.”

A Shortcut to the Road Ahead

The key to this book lies in the unexpectedly central role of electrical charge throughout nature. The book will take you on an electrical journey. It will explore how an appreciation of the role of electrical charge might offer a way forward to a simpler and more straightforward understanding of the science of everyday life — the science that lets us understand how the world works.

You might presume you already *know* how the world works. After all, you regularly think about explanations for natural phenomena. It’s raining — so you surmise that those droplets must be pulled to the earth by gravitation. Suppositions like that can feel satisfying; you’re comforted by your apparent understanding of nature. Who needs any further comprehension?

Yet, even in that seemingly straightforward realm, matters are not so straightforward. A scientific study challenges that simple gravitational interpretation (see Chapter 8): In drawing those raindrops toward the earth’s surface, at work is something beyond just one mass pulling another. To explain the observed high speed of descent, another force must be at play.

Like the falling raindrop scenario, presumptions exist about the mechanisms underlying many everyday phenomena. Those mechanisms may seem reasonable on the surface; we're inclined to accept them as valid, and most of them probably are. Nevertheless, we cannot be sure, especially if said mechanisms are burdened by embarrassing anomalies, or contradictions. Determining whether alternative explanations may better fit the evidence requires us to dig more deeply. Such excavation could potentially uncover fresh interpretations that prove less clumsy, more elegant, and ultimately more appealing. We can't know until we look.

To begin the search, I invite you to accompany me along that journey of exploration. I will first offer you a capsule preview of the subjects covered in the Roadmap — a preview of the preview if you will. As you will immediately see, the focus lies squarely in the proposed central role of electrical charge. Following that teaser, we will explore the subject matter more substantively.

- **Earth Physics:** Most of us envision electrical charge forces as puny. Is lightning an exception? Could electrical charges plausibly generate colossal amounts of force?

- **Earth-Centered Dynamics:** Wind gusts are natural, but how are they generated? If the answer is not immediately obvious, then here's another question to think about: What makes the earth spin? Could both of those phenomena possibly involve electrical charge forces?

- **Weather:** In generating those thunderous cloudbursts, might electrical charge play a more central role than the usual suspects, temperature, and pressure? Could electrical discharge be more than just a side effect?

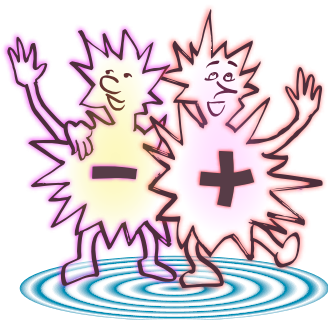
- **Gravitation:** We think of gravitation as arising purely from the attraction of masses. That paradigm mostly works; but sometimes it fails. Is it outlandish to consider whether electrical charge forces may contribute in some unsuspected way?

- **Learning to Fly:** Yes, birds fly by flapping their wings. But some species rarely flap. Could electrical charge improve our understanding of how birds remain aloft? Or, how Frisbees float? Or, how spiders can make their way from land to distant ships, as Darwin once observed? Indeed, could spiders really *fly*?

- **The End of the Road(map):** Could our brief journey of exploration lead to a set of foundational principles, providing solid ground for trekking into the scientific future?
- **Summing Up: Unlocking Nature's Mysteries:** Guidelines for effective probing.

Next, I will launch into a more detailed overview of how this book develops a fresh approach to issues that have frequently bedeviled both lay people and students of science alike. It will raise questions you might never have thought to ask.

But First, How Can We Understand Electrical Charge?



The term “charge” may seem as remote from common experience as Pluto. Even though we live in a pervasively electrical culture, the concept of electrical charge would seem for most to lie well beyond our sphere of understanding.

Let's begin with simple elementary-school science. On some winter's day, you may have used a comb and wondered how the static electrical charge gave you that flyaway hair. Charge seemed involved; yet, somehow, the phenomenon remained shrouded in mystery. Perhaps it still does. Even the very definition of charge may seem elusive: Protons constitute the unitary positive charge, electrons the unitary negative charge — but what exactly is charge? Can we really define it? Or, is it merely a postulate?

In this context, I'm reminded of the plight of my colleague, Bill, who began his career at an East Coast children's science museum. His duties included telling kids about electricity. To his surprise, he found that he couldn't. Despite his rigorous grounding in electrical science, children asked questions about those moving charges that he couldn't honestly answer. Frustrated, he decided to leave his position and came to work at my university. Bill continued working to understand the basis of electrical

phenomena as a sideline, eventually arriving at what he felt to be a more nuanced view of how those charges might really flow.

Like Bill, you might (or might not) have some inkling of how electricity is supposed to work. However, you may still wonder whether a book about a phenomenon as seemingly elusive as electrical charge could really matter.

Charge could matter more than you think. First, the *physics* of electrical charge matters because even relatively small variations of charge can yield surprisingly powerful effects. Try stuffing a bunch of negative charges together — they strongly resist. Most undergraduate science students can calculate the repulsive force among those charges, which turns out to be unexpectedly huge. I know I'm jumping the gun here, but I can tell you that its magnitude will probably astonish you (see next section). Given such power, charge-based forces could have impressive potential as drivers of natural phenomena.



Second, the *concept* of charge matters because it may offer potentially useful ways to explain natural phenomena for which satisfying explanations do not yet exist. I'm talking about phenomena that may range from the genesis of weather all the way to the flight of gliders. Charges could turn out to be central protagonists.

Those two attributes, concept and underlying physics, motivate us to forge ahead. The potential for fresh interpretations could open new pathways to understanding — not only satisfying our innate curiosity, but also providing avenues for practical exploitation. The discovery of X-rays made possible the field of diagnostic imaging, in the same way as the discovery of microbes enabled the development and production of life-saving antibiotics. Fresh understandings inevitably lead to practical

applications, some of which could never have been conceived in advance of the discovery that spawned them.

So, we press on with our journey of exploration. We admit that electrical charge has no easy “definition.” It is nothing more than a postulate — a simple proposition that has gained acceptance by proving its worth and may yet prove useful for gaining further understanding.

To guide you along this quest for fresh understanding, I offer the following roadmap. As we head toward unexplored territories, it should help provide orientation.

SECTION I: The Charged Earth

Charges lurk practically everywhere. Even the Earth, itself, bears a net negative charge, with complementary positive charge residing in the atmosphere. This fact will come as news to many, but not to geophysicists and atmospheric scientists, who mostly recognize these separated charges as a confirmed fact. On the other hand, even some of those specialists may not fully appreciate the force-generating potential carried by Earth’s charge, or by charges generally.

To illustrate their vast strength, imagine the following scenario. You are lying on the ground, with a friend suspended one meter above you. (The suspension method is irrelevant.) Go ahead and imagine — I’ll wait.

Now suppose further that you could remove one percent of the electrons from each of those two bodies. Eliminating those negative charges leaves both of you positively charged, so you repel one another. How large is that repulsive force? Stated a different way, how much weight would you need to place atop your friend to prevent her from being thrust further upward due to the repulsive force?

Calculated by physics Nobelist Richard Feynman, the answer beggars the imagination: Under these stated conditions, you’d need the weight of the entire earth!



Charge forces are surprisingly strong, and therefore full of potential to do work.

Continuing in that same vein, consider the concept of air pressure. According to the conventional view, air pressure comes from the weight of the atmosphere pressing on the earth's surface — much like a lead block pressing on the earth. Air, however, is nothing like a lead block — it's a gas. Unlike solids and liquids, whose constituent molecules interact with, or even cling to one another, gas molecules tend to keep their distance. That's the very definition of a gas. If those air molecules remain separated, then how can their *collective* weight press on the earth? The lowest molecules surely can press, but what about the upper ones? If they're mainly disconnected, then how can they press collectively?

For resolving this enigma, explanations (mostly based on molecular collisions) can be found in the scientific literature, although those explanations raise questions that need answering. It's a cascade of queries. An alternative path comes from the presence of charge: Since the atmosphere bears positive charge and the earth bears negative charge, those two entities will attract. *Could the resulting attraction suffice for keeping the atmosphere clinging to the earth, thereby manifesting as pressure?*

SECTION II: Earth-Centered Dynamics

Have you ever wondered what creates the wind? Or what force propels a wind gust? Questions of that sort often stymie atmospheric scientists. Expedient responses invoke pressure gradients — but what establishes those gradients? Few scientists seem to exhibit very much interest in answering that simple question.



Once again, a candidate for explaining matters could reside in electrical charge. Since positive charge pervades the atmosphere, any difference in the amounts of charge between two nearby atmospheric regions will impel the excess charges to flow into the area with fewer charges. *Could such airflow underlie what we experience as wind? If not, then what creates a wind gust? And how can those gusts sometimes be so localized?*

Here's a related question that you have probably not spent much time worrying about: What force keeps the earth spinning on its own axis? Did the earth get a kick-start long ago, and continue to spin because of its immense inertia? Inertia could certainly maintain spin — but for a few *billion* years?

If that seems questionable, then consider an alternative hypothesis: A continuous supply of energy propels the spin. Could any such energy come from our benevolent sun? *Can you imagine how the sun's energy might create localized gradients of atmospheric charge, which propel airflow over the earth's surface (wind), shearing past the Earth to keep it spinning?*

If you cannot, then please do read on to see whether a proposed mechanism makes sense to you.

SECTION III: Weather

Forecasters know a lot about weather, yet they have often failed to predict monumental events such as New England's massive snowfalls in 2014 and 2015. Even forecasts for rain the next day sometimes come with only a 50 percent probability. What additional variables might help us improve those forecasts? How can we *understand* weather?

Consider our emerging protagonist: electrical charge. Lightning reveals that clouds may bear charges. Hence, charge could conceivably serve as a useful lens through which we can examine the genesis of weather. Current weather hypotheses remain vague. They leave unresolved questions such as the following: How did those charges get into the clouds in the first place? And how might the clouds' charges interact with the earth's charges?

Seemingly ignored by many mainstream scientists, evidence originating from decades ago shows that it's not just thunderclouds that bear

charge, but all clouds. That includes even those gentle-looking, puffy, white, fair-weather clouds. Evidence from our own laboratory concurs: A cloud bears negative charge because each one of the tiny water droplets that make up the cloud bears a net negative charge.

But, wait a minute! We know that negative charges repel one another, leaving us with a paradox: How could these like-charged droplets draw together to form a cloud? How do they “condense”?

And once formed, why do clouds remain suspended? Suspension seems entirely illogical: Clouds mainly comprise water droplets, but garden-variety water droplets routinely fall to the earth. Yet clouds don’t fall; they stay aloft. It’s been calculated that the water contained in a large cumulonimbus cloud may weigh up to a hundred million pounds. Nevertheless, those hefty clouds rarely plummet to the earth. Could the cloud’s negative charge repel the earth’s negative charge strongly enough to keep those clouds aloft? Is that why clouds float?

And if so, then why does it rain? You’d think that gravitation might do the trick. But, if charge repulsion keeps the cloud droplets suspended, then how would gravitation suddenly take over and pull those drops down to the earth?

And further, a dark cloud will hold its water sometimes, while at other times releasing its contents in a downpour. What turns the faucet on?

Finally, when the rain does fall, why does its intensity vary so much? We may experience anything from a gentle sprinkle to torrents of rain accompanied by driving winds that leave you chasing your hat down the street. How does this happen? And why do rainclouds sometimes grow into typhoons, or spawn tornadoes that can twist to such catastrophic effect?

Could some of the answers lie in an unrecognized role of electrical charge?



SECTION IV: Gravitation

Many of us have learned that masses attract. Your mass attracts the earth's mass, and vice versa. Such mutual attraction grounds you to the planet's surface. This understanding of gravitation seems entirely reasonable, but where does that leave you when you begin to wonder *why* masses attract?

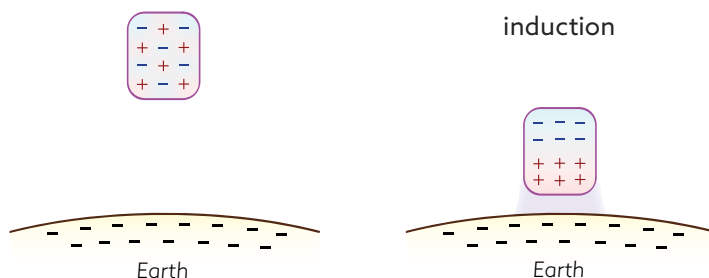
When I asked this blunt question to several physicists, they became frustrated — seemingly embarrassed by their inability to respond in a simple, intuitive way. Consistently, they invoked the recondite subject of Einsteinian space-time geometry. That kind of response appears to satisfy most physicists, but the rest of us find that our efforts to reach a straightforward account of gravitation come to nothing. Plainly put, we are left with no clear sense of how this familiar force of the universe works. We resign ourselves to taking the physicists' word for it because we can't easily articulate the reason why masses attract.

Thinking within the framework of charge raises another possibility. If the earth is charged, then could the *charge* of the earth contribute to the gravitational pull? This idea will surely seem foreign — I know. But please appreciate that standard gravitational theory is beset with multiple anomalies, more than commonly thought. Especially at short mass-to-mass separations, and also at long separations, those anomalies become serious, requiring large “correction factors” to fit the theory. We may opt to sweep those anomalies under the carpet and press on; or we can explore contributions that might be less burdened by pesky anomalies, too many of which inevitably raise questions.

Regarding the prospect of charge-related contributions, it may surprise you to learn that towering scientific figures including Einstein, Faraday, and Feynman, along with some present-day scientists, have previously considered electrical or electromagnetic origins of gravitation. The concept is less radical than you might think.

Consider the following potential mechanistic contribution, involving charge forces.

According to Faraday's law, a charged body induces opposite charge on the closest surface of anything nearby. Thus, Earth's massive negative



charge will induce positive charge on the bottom of any mass situated on the earth or just above it. The top of that mass, meanwhile, will contain equal negative charge.

The earth's negative charge will pull on the positive charge situated on the lower surface, while pushing on the negative charge on the far surface. The pulling force will always win out — it will be marginally stronger than the pushing force because the positive charges lie closer to the earth's surface than the negative charges. Hence, the net force will be weakly attractive. But then again, physicists characterize the gravitational force as “extremely weak,” some 10^{40} times weaker than the electromagnetic forces presumed to hold atoms together.

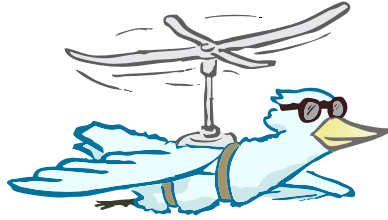
So, it's worth asking: *Could any such charge-based attraction contribute to earthly gravitation? If so, then by how much? And could such attraction help account for cosmic gravitation as well?*

SECTION V: Learning to Fly

After considering the weighty problems of cosmic gravitation, we turn our attention to objects somewhat closer to Earth — namely birds and airplanes. Many of us feel satisfied with our understanding of how those objects fly, but this section raises some troubling questions.

Take birds, for example. Everyone “knows” that birds fly by flapping their wings. Yet, peering through my living-room window, I routinely see eagles gliding substantial distances with hardly a flap. A seemingly effortless flight might include directions south, north, east, and, also west, in which the eagle may variously lose and even gain altitude. Eagles seem capable of traveling wherever they wish with no obvious difficulty — with practically no wing flapping.

Scientists have offered a variety of simple explanations, among them: eagles find updrafts; they're lightweight; they're aerodynamically



constructed; *etc.* I have even heard some attempts to “explain” this phenomenon by suggesting that eagles “soar,” as though that constitutes an adequate explanation. Those accounts come almost reflexively; yet rarely does anyone question whether they suffice. *Do we really understand how birds can maneuver through the air without flapping their wings?*

I’m certainly aware of arguments based on wing contour. You may be surprised to learn, however, that like planes, birds can fly upside down (Chapter 15). If airfoil shape keeps birds suspended, then why wouldn’t upside down flight bring embarrassing plummets to the earth?

Without fully divulging my proffered explanation, let me just tease you with the potential applicability of one well-recognized phenomenon: the triboelectric effect. Any object passing through the air will acquire negative charge. Similarly, a fixed object with a stream of air flowing past, will likewise acquire negative charge. (Think of your blow dryer, fluffing out your just-dried hair by charging each strand.) Hence, a soaring bird will inevitably acquire negative charge. The presence of that charge raises a question: Could the soaring bird remain aloft at least in part because the negatively charged bird repels the negatively charged earth?

In short, could electrical forces be relevant for flying? Might this phenomenon hold some relevance for airplanes as well?

SECTION VI: Moving Ahead

Similar questions arise for the issue of how fish swim. What, exactly, propels fish forward? You may feel as though responding with “tail swinging” easily answers that question. Though mainly pushing sideways, to some extent a swinging fin also pushes water backwards, thereby propelling the fish forward. The concept seems simple enough — but in ordinary viscous water, could any such tail-swinging mechanism generate enough propulsive power to accelerate black marlins to speeds in excess of 60 miles per hour?

If not, then how do fish swim?

And, slightly tongue-in-cheek, if nature has settled on tail swinging as the optimal means for achieving aquatic locomotion, then why haven't marine engineers even *thought* to emulate that process? Given their ingenuity, you'd think that implementation ought to be straightforward. So, how come the Queen Mary II doesn't propel itself forward using the swinging-fin mechanism?



Finally, consider sailboats. How those boats move downwind seems like a no-brainer, to be disposed of in a single thought: The wind pushes on the sails, and off you go. However, sailboats can also move upwind. Modern sailboats manage to advance as close as 40 degrees off the wind. Racing boats can sail closer to 30 degrees. Iceboats, by comparison, can head practically dead into the wind. Those cold weather sailing vehicles move *against* the wind, sometimes reaching speeds up to three times the wind velocity. Imagine advancing into a gale-force wind blowing fiercely on your face. How can that happen?

To explain this anomaly, sailors with a scientific bent may reflexively invoke “Bernoulli’s principle,” a well-known principle of fluid dynamics. But as we shall see, the argument is far from satisfying. So, the question arises: Could sailboats plausibly head into the wind in the absence of something extraneous pushing them or pulling them in said direction? And if they cannot, then what’s the nature of the force that might propel them?

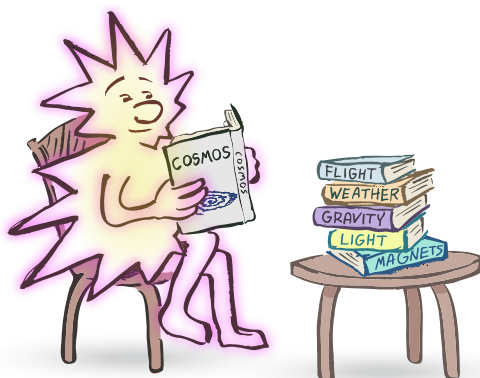
Could unsuspected charge forces possibly extricate us from the horns of this dilemma?

SECTION VII: Summing Up: Unlocking Nature's Mysteries

Numerous questions about how things work, both here on Earth and in the broader universe, remain unanswered. This book attempts to find answers. As I wrote this book, I tried to measure up to the earlier-mentioned standard (see Preface): “You do not really understand something unless you can explain it to your grandmother.” The grandmother I was blessed to know had no scientific training. Nevertheless, in spite of a few intricacies sprinkled throughout the book, and notwithstanding some immigrant-language challenges, I would hope that she could have understood most of what follows in this book.

I can condense the book’s message down to a single pervasive theme: the overarching role of electrical charge. We find charge everywhere. And, it generates forces far beyond our intuitive sense of things. That makes electrical charge a natural candidate to consider as a key driver of many physical phenomena, as the rest of this book will attempt to demonstrate.

As you’ve undoubtedly noted from this Roadmap, the material in this book will stray far from well-trodden scientific pathways. Mainly, we will be exploring uncharted terrain. I do not profess that all of what follows necessarily represents ground truth; I’m confident that it won’t. Nevertheless, I hope this adventure will open your eyes to operative mechanisms that you might not have thought to consider, some of which, I hope, may illumine the workings of our natural world.



Praise for Charged

“*Charged* is the book I seriously wish had been available before I entered engineering school many years ago. It is a marvelously readable tour through the underpinnings of how our reality appears to work — that often flies in the face of convention ... But always makes great sense. Absolutely brilliant!”

—John L. Petersen, Founder and President of the Arlington Institute

“Gerald Pollack is one of my favorite scientists. He asks penetrating questions about everyday phenomena, like clouds, the rotation of the earth and the flight of birds and comes up with radical yet simple suggestions for a new scientific vision. He reveals that our current scientific understanding, which we usually take for granted, is often a misunderstanding that lulls us into a false sense of certainty. His book is a breath of fresh air, and indeed gives a new way of thinking about fresh air itself. *Charged* is clearly written with delightful diagrams and drawings which make concepts easier to grasp. It is rare to encounter such a brilliant, original and stimulating book that changes the way we see the world around us. I am very grateful to Pollack for writing it.”

—Rupert Sheldrake, PhD, biologist and author of *Science Set Free*

“A lot of my culinary creativity and insight is inspired by my motto: question everything. Gerald Pollack is an explorer and visionary who figures out the fundamental questions we all need answers to (even if we haven’t realized it yet) and explains them with lucidity and clarity. *Charged* will open your eyes, your mind and your understanding.”

—Heston Blumenthal, award-winning chef, cookbook author
and restaurateur, including 3-Michelin-Star The Fat Duck

“Delightfully illustrated and perspicuously written, *Charged* uncovers and untangles spellbinding anomalies of everyday life — from the unexpected origin of clouds, winds and raindrops to that of falling and flying of objects, animals, and machines — through the pervasive role of electrical attraction and repulsion in the natural world. Pollack’s proposal is profoundly simple, bold, original, democratic, relevant, and grounded. This book shall captivate children and Nobel laureates alike.”

—Alex Gómez-Marín, professor of the Spanish Research Council
and director of the Pari Center in Italy

“Prof. Pollack is extrapolating upon his great discoveries. This is the kind of thinking needed to advance our paradigms scientifically. Reading this book changed how I look at ... Everything!”

—George Wiseman, Alternative Energy Innovator and
President of Eagle-Research

“Gerald Pollack has done it again! Pollack guides us masterfully through the complex topic of electrical charge and how it impacts life as we know it. Painting a completely new picture with compelling and captivating writing, *Charged* is a must-read book for anyone interested in science!”

—Catherine Clintion, Naturopathic Physician, Author, Speaker

“*Charged* forces you to walk through the world with eyes a lot more open than before; you cannot unsee the many observations once pointed out. It presents a mind-boggling series of paradoxes that scientists seemingly worked around for decades without questioning what now seem to be mere assumptions rather than proven concepts. The material in the book has the potential to be the source of many disruptive technologies across a wide area of applications.”

—Achim Hoffmann, PhD, CEO of Ocane Ltd.

“This is a mind-blowing book! For the first time I have found a reasonable explanation for most fundamental phenomena, from cloud formation to the rotation of the Earth and the origin of the magnetic field. This is a real scientific thriller, and a must read for all open-minded people, regardless of their profession and education. Ethan Pollack’s illustrations make this book lively and sometimes even funny.”

—Konstantin Korotkov, President of Bio-Well Companies,
USA and Spain, author of 17 books

“Thank you, Prof. Pollack, for this insightful book. It asks fundamental questions about natural phenomena that we see every day, and draws bold conclusions about how they really work. All involve electric charge. Reading this book was an exciting journey, full of intellectual pleasure.”

—GunWoong Bahng PhD, Leading Professor, SUNY Korea

“*Charged* presents a cogent case for alternative theses that challenge the generally accepted theories describing some well-known, but not necessarily well understood phenomena. The theses delve into details that are not always present in the accepted theories and are certainly worthy of serious consideration and further study.”

—Susan Schirott, The Thunderbolts Project

“Pollack presents a groundbreaking synthesis that challenges long-held assumptions about how nature really works. With its rare interdisciplinary perspective, CHARGED deserves careful study by all intelligent people, not just scientists but anyone with even a modicum of curiosity.”

—Roberto Germano, CEO of Promete, CTO of OXHY

“Another foundational book from Gerald Pollack. In this new work, Pollack builds on his discoveries of charge separation in water to extend straight out to the edge of the cosmos. Understanding electrical charges as a veritable counterforce to gravity gives us a new future to shape. This is the next textbook for all our science. I read it with glee. Every new revelation about how Nature works came with a satisfying “click” that made sense. Read it in little “sips” to hold on to the unveiling of wonder.”

—Gina Bria, Founder of Hydration Foundation

“A reminder that the true purpose of science is to understand and appreciate the true workings of nature. *Charged* continues this exploration. It redirects focus to matters that should have been the center of attention long ago.”

—Ari Pentilla, CEO of Prorink

“Another proof of Pollack’s open mind to look at common phenomena with fresh eyes and question the status quo. And again a very pleasant read, with a very didactic and fun writing style. A must read for students, who should know that what they are taught may not yet be the ultimate truth, and to urge them to explore.”

—Everine van de Kraats, PhD, Founder and Director of
World Water Lab and World Water Community

“I was positively astounded by this book. There are countless positive provocations for our sleepy, not to say clinically dead, ‘incremental’ scientists, especially in physics. In fact, I fear the electric shocks stemming from this book will probably not suffice to rouse most scientists from the dark tomb in which they have happily shut themselves. However, I do hope it will help to awaken those who have not yet been fully gripped by the whirlpool of modern scientific religion. It is a book that brings new light, new challenges, and new perspectives on how to deal with nature in a much simpler way.”

—Igor Jerman, PhD, Director of Bion Institute, Slovenia

“Pollack’s book explodes the bubble: electrical charge is a super power. He illustrates — quite literally with great drawings — that if one electron is removed from each of two vertically stacked bodies, the repulsive force will be so high that in order to prevent the rise of the upper body, you would need to pile 50,000 trucks on top. This revelation has dramatically changed my own perception of the material realm. Schools must include it right away. So many things are governed by charge and charge collapse — but how can charge collapse? Pollack explains all of this, and how it directly governs the natural world around us. And he presents it in an intriguing, readable way that cannot help but draw you in.”

—Ralf Otterpohl, Dr.-Ing, Professor Emeritus,
Hamburg University of Technology

“The same scientist who revolutionized our understanding of water a decade ago, is about to do the same to the role of electric charge in the world... I almost fell off my chair several times when reading the Introduction, but chapter after chapter convinced me that he had very solid evidence for every claim. And Prof. Pollack’s courage for challenging the status quo — rarely popular — is astounding and inspiring!!”

—**Yonah Alexandre Bronstein, PhD, President and CTO of ASTAV, Inc.**

“In the current century, the electroneutrality paradigm is being challenged by experimental results in areas ranging from atmospheric science to synthetic chemistry. This book is an excellent contribution, presenting a wealth of information illuminated by the original thinking and provocative style of a leading contributor to knowledge on Earth’s surface (and beyond).”

—**Fernando Galembeck, Emeritus Professor, Unicamp, Brazil**

“This book demystifies the pivotal role of electrical charge in nature, to be understood by everyone. By applying ‘Occam’s razor’ of simplicity, Pollack enables the scientist as well as the novice to understand and value the profound connections between electricity, water, and all life.”

—**Stuart Rudick, EverBlue Ventures**

“Here, science is practiced as it should be. A researcher makes his own observations and experiments in nature and then begins — wide-eyed, curious and impartial like a child — to investigate whether there is already evidence from others that supports what he has concluded. It takes a lot of courage for a scientist to question common narratives. At the same time, it takes perseverance not to be swayed by ignoramuses and nay-sayers. I hope that the book — as it did for me — will also encourage other researchers to ‘stick at it.’”

—**Dr. Cornelia Renate Gottwald, Magnetic Field Therapist, Germany**

“Many anomalies don’t fit the currently accepted paradigm. Through these anomalies, a new paradigm may emerge. Pollack follows this path, wielding Occam’s razor (the principle of simplicity) to reveal multiple new paradigms of understanding, all centered on electrical charge. He demonstrates the centrality of electrical charge in the understanding of so many familiar phenomena involving the Earth and the entire universe. The result is mind-blowing.”

—**Won H. Kim, Professor, Yonsei University, Korea**