Chapter 1
Introduction

THIS is a story about you.

IN this very moment, you are consciously reading this sentence in your mind. You are aware of your body and the world surrounding you. Your breath is flowing through your body.

EVERY day you wake up. Instantly, the memories of who you are enter your mind. You start to sense yourself and the external world you woke up to. Then you open your eyes. Everything appears familiar and unspectacular.

But how can you trust this emergence of a world? Can you be certain of the accuracy of the perceptions you are experiencing and the faithfulness of the memories in your mind? Are you perhaps just a brain kept alive in a vat in a dark room, receiving fabricated electrical impulses, stimulating it into perceive a fictitious world? Or did you never actually wake up? Are you experiencing an episode of false awakening, the phenomenon of dreaming that you woke up, where the vividness and crispness of the conscious experience trick you into believing its authenticity? Or could you be inhabiting a simulated reality, designed to emulate "true" reality? Or are you currently incarcerated in a psychiatric institution and your mind is hallucinating an entire world of fiction in order to not have to face its own pathology? The array of conceivable alternative explanations for your experience of a reality can be frightening.

IMAGINE, for a moment, that you are a member of an isolated society. You were never exposed to the collection of human ideas shaping the world today. As a child, your inquisitive mind, exploring your inner and outer reality, was never influenced by human thought traditions, spanning several millennia. You were never told any tale sourced from the competing brands of theology we today find distributed around the globe. You never felt the existential angst that can be triggered by contemplating philosophical problems related to existence, knowledge, reality, and the human mind. You never felt exalted and overwhelmed by the vastness of understanding contained within the edifice of science.

J. B. Glattfelder, *Information–Consciousness–Reality*, The Frontiers Collection,
https://doi.org/10.1007/978-3-030-03633-1_1

How would you then explain your existence? How would you go about answering the questions “What is reality?”, “What can I know?”, and “Who am I?” Assuming a robust skeptical demeanor, you would probably arrive at a fundamental philosophical insight (Descartes 1637):

> I think, therefore I am.

The only thing you can truly be sure of is the reality of your own subjective experiences at this very moment. Everything else is questionable. Moreover, musings about the meaning of life would perhaps, in the final analysis, gravitate towards another fundamental philosophical observation, encapsulating the mystery of existence (Leibniz 1714):

> Why is there something rather than nothing? For nothing is simpler and easier than something. Furthermore, assuming that things must exist, we must be able to give a reason for why they must exist in this way, and not otherwise.

How can you ever be certain about anything? Gazing at the night sky, you would be filled with a deep longing for knowledge.

For centuries, people hoped that science, the abstract mathematical understanding of the physical world, would shed light on the true nature of reality. Indeed, the explanatory power of science has exploded and with it humanity’s capacity to manipulate reality. The emergence of science is a story of how the human mind gained intimate knowledge of the workings of the universe and how this expertise gave us one of the greatest gifts: the fruits of technology.

However, in an act of cosmic irony, this expanding continent of knowledge found itself surrounded by ever longer shores of ignorance. We have been able to probe the unseen subatomic world, only to discover quantum weirdness at its heart. Subatomic particles that display two contradictory properties, depending on if and how they are observed (wave-particle duality). We encountered an insurmountable fundamental physical limit on how much we can ever know about a particle (uncertainty principle). At the quantum level of reality, any certainty is lost and measurements can only be expressed as probabilities (wave function). For instance, the location of an elementary particle is probabilistic, meaning that it could be observed anywhere in the universe with a sufficiently low probability. As a result, a subatomic particle can appear at places which should be impossible (quantum tunneling). The discovery of a zoo of elementary particles and the mirror-world of antimatter revealed a far greater structure to reality anyone had dared to dream of. Empty space (the quantum vacuum) was found to be permeated with energy and nothingness became something (zero-point energy, Casimir effect). Dramatically, the very act of measuring a quantum system changes its properties, appearing to give the observer a special status (measurement problem). Indeed, some experiments suggest that the choice of an observer in this moment can alter the past (delayed choice experiments). To this day, we are baffled by the marriage of quantum entities that allows them to stay connected and be both instantaneously influenced (non-locality, violation of local realism), regardless of the spatial separation between them (entanglement).

Indeed, we are truly surrounded by perplexing enigmas. There exists an upper limit to how fast information can travel in the universe (the constant speed of light) which results in the surprising malleability of space and time (special relativity), where the passage of time can vary for each observer. Even time itself emerged as a problem child—a notion so central to our experience of reality but also so far from our intellectual grasp, as it appears to be an emergent property. At the core of reality we find no foundation. Even matter itself eludes the grasp of our minds—neither the notions of fields nor particles suffice to capture its essence. Exasperatingly, causality cannot be upheld in time alone. The question whether *A* caused *B* to happen, or vice versa, is futile. However, causality reemerges in the mystifying weaving of space and time into the fabric called space-time, an inconceivable four-dimensional atemporal reality where the borders of space and time are blurred. Now the force of gravity turns out to be an illusion, created solely by the unseen curvature of space-time (general relativity). The discovery that our universe is forever expanding at an accelerated rate (dark energy) may mark one of humanity's greatest cosmological achievements, but it is a profoundly unsettling fact. Furthermore, 95% of the contents of the universe is, embarrassingly, not accounted for in our theories of the cosmos (dark matter and energy). Then, modern theoretical (high-energy) physics has reached a dead-end, after string theory was hailed as the light-bringing savior decades ago. The list of paradoxes we are faced with goes on and on. It appears as though every explanation creates more new problems—the closer you look, the more you see. Most humblingly, the success of science rests on two miraculous circumstances. One is "the unreasonable effectiveness of mathematics in the natural sciences" and the other is the fact that simplicity lies at the heart of complexity. These are the two pillars our whole human knowledge generation rests upon. To this day, we can only shrug in the face of this cosmic design and be grateful that we do not find ourselves inhabiting a universe that is fundamentally incomprehensible to our minds.

Of all the failings of science, perhaps the most pressing is its inability to comprehend life and consciousness, going to the very core of our being. The most complex structure we ever encountered in the universe is our brain. Through it, we experience and perceive the physical world and ourselves. We are minds incarnated in flesh, able to discover and create science, enabling us to manipulate and engineer reality at will. How can that which is closest to us be so elusive? Why don't we understand the nature of consciousness? How does life encode such breathtaking complexity in a zygote which triggers self-organizing biological structure formation (embryogenesis)?

Even more troubling, there have been a multitude of cosmic coincidences happening, in order for the universe to have reached this exact point in its 13.8 billion year history, where you now happen to be reading this sentence. For instance, the perfect fine-tuning of physical constants allowing a complexly structured universe to emerge from the primordial cosmic energy soup (Big Bang); the unseen universal force driving the cosmos to ever greater structure and complexity (self-organization and emergence); the forging of heavy elements in exploding suns (supernovae), like carbon and oxygen; the special properties of water and carbon—a necessary prerequisite for life; the exact positioning of Earth in our solar system; the accumulation of (liquid!) water on Earth; the emergence of the first biological replicators on Earth; the appearance of cyanobacteria, the first organisms able to harness the energy emanating from the Sun by unlocking the secret of photosynthesis, an event marking the beginning of the terraforming of an oxygen-filled atmosphere; the self-organized engineering of complex life forms from (Eukaryotic) cells; the Cambrian explosion, an evolutionary burst 540 million years ago, filling the seas with an unprecedented diversity of organisms; the emergence of insects displaying social behaviors; at least a dozen extinction events, some resulting in the eradication of nearly all of the biodiversity on Earth, rendering the evolutionary process chaotic, highly path-dependent, and extremely unique; the extinction of dinosaurs allowing mammals to exit their niche and start world domination; and the demise of all other human species leaving one lineage as the sole conqueror of the solar system, due to the emergence of consciousness and the capacity for abstract thought—igniting language and culture—in the brain of Homo sapiens. This stunning tale of cosmic evolution, fraught with chance, has attracted very different explanations:

E1 It is all just one big coincidence and happened by pure chance. We know the fundamental laws of nature and that is all there is to say. [Materialism, scientific realism]

E2 A God created the universe in this fashion. Perhaps 13.8 billion years ago or perhaps 6,000 years ago with fictitious properties making the universe appear older (or even 5 seconds ago, with false memories implanted in all human minds). [Creationism in Abrahamic religion]

E3 Reality is a vast and impermanent illusion (*anicca*) comprised of endless distractions and suffering. The quest of the mind is to cultivate a state of awareness, allowing the illusion to be seen for what it is. Then the enlightened mind can withdraw from the physical realm and enter a state of pure bliss. [Buddhism]

E4 Only the Self exists. Life is the endless play of the Self (*lila*) losing itself only to find itself again in a constant game of hide-and-seek. [Hinduism]

E5 Only pure consciousness exists. In endless cycles, it manifests itself as separate physical embodiments, allowing for an experiential context, only to merge in unity again and start afresh. [Spirituality, panpsychism]

E6 We are dreaming this life and will some day “wake up” to a richer reality which is unimaginably more lucid and coherent. Physical death marks the transition of consciousness from the dreaming state to a higher-dimensional reality or maybe a reality entirely outside the realm of space and time. [Esotericism variation]

E7 We live in the multiverse, the infinite set of all possible universes. As a consequence, we naturally find ourselves in that corner of it which allows for intelligent and sentient life. [String/M-theory, cosmology, many-worlds interpretation of quantum mechanics]

E8 Our physical three-dimensional universe is a hologram that is isomorphic to the quantum information encoded on the surface of its boundary. [Holographic principle, AdS/CFT duality]

E9 We inhabit a simulation that has these features programmed. [Simulation hypothesis]

Every justification has its proponents, be they spiritual, religious, philosophical, or scientific. Especially explanations $E7$ to $E9$ are espoused by people who have been greatly exposed to the mathematical underbelly of reality in the form of theoretical physics or quantum computation. Of course, every angel of attack has its drawbacks. For instance:

E1 This reasoning is simply an assertion without any explanatory power.
E2 Which God (or gods)? What is the nature of God (or gods)? What causes God (or gods)?
E3 How does one experience this and how does one reach enlightenment?
E4 Who or what is choreographing this grand play?
E5 Where does this pure essence of consciousness reside and how does it invoke the physical?
E6 Who is dreaming and what is the nature of the waking reality?
E7 An unimaginably rich and transcendental structure is invoked to explain our reality.
E8 Is M-theory correct?
E9 What is the nature of the simulation and in what computational entity is it running?

As ever, certainty appears like a futile quest.

To add insult to injury, the understanding we have managed to gain about the mechanisms and processes in our brains paints a gloomy picture. Neuroscience has uncovered that our normal perception of reality is a hallucination guided only by a little external input. The conscious mind's role is to narrate and justify, in hindsight, the decisions reached by the many subconscious subroutines in the brain. Tweaking the neurochemical balance in the brain can lead to the firsthand, immersive experience of realities, radically different to the default mode of sober consciousness. These are realities that defy and transcend any conceptualization attempts and which can only be subjectively experienced—through altered states of consciousness. Many experiments have shown that the simple expectation of a particular experience changes how we perceive it, from pleasure to pain. We now also know that memories are distorted and can be false, as they are actively constructed in the very moment of remembering, rather than being retrieved from a storage archive in the brain, cataloging all past events. Other experiments have uncovered how we continuously, and embarrassingly, behave in irrational manners, while at the same time taking pride in the belief of our rational capabilities. Perhaps most troubling, and explaining a lot about the state of the post-truth world we live in today, is the following observation: Grossly incompetent people lack the skill to identify their own lack of skill, leading to an inflated and distorted self-perception, while highly competent people are troubled by doubt and indecision, resulting in a self-conscious and distorted perception of themselves (Dunning-Kruger effect).

THIS story is also a tale of our possible role in the universe, offering a novel approach to all the enigmas we are faced with—all the existential challenges that keep mocking us. It hinges on the question "Could there be something we don't yet know about ourselves and the universe, the knowledge of which could change everything?" Are we harboring erroneous concepts in the contemporary scientific worldview? Can we rectify this by exploring new ideas? For instance, the notion that the foundation of reality is based on information. Or the radical possibility that consciousness also plays a fundamental role in the universe. Can information, consciousness, and reality be braided into a unified fabric of existence?

Plato was the most famous student of Socrates, the Greek philosopher who is considered to be the father of Western philosophy. He proposed the following thought experiment, captured in an analogy called the Allegory of the Cave. It appeared in his Socratic dialogue called *The Republic*, around 380 B.C.E. In a nutshell[1]:

> The story is a description of a group of people who have lived chained to the wall of a cave all of their lives, facing a blank wall. The people watch shadows projected on the wall from objects passing in front of a fire behind them, and give names to these shadows. The shadows are the prisoners' reality. It is explained how the philosopher is like a prisoner who is freed from the cave and comes to understand that the shadows on the wall are not reality at all, for he can perceive the true form of reality rather than the manufactured reality that is the shadows seen by the prisoners. The inmates of this place do not even desire to leave their prison, for they know no better life.
>
> Like the fire that cast light on the walls of the cave, the human condition is forever bound to the impressions that are received through the senses. We cannot free ourselves from the phenomenal state just as the prisoners could not free themselves from their chains. If, however, we were to miraculously escape our bondage, we would find a different world. In other words, we would encounter another "realm," a place that is the source of a higher reality than the one we have always known.

What if you were the fortunate convict able to escape your prison of perception and discover a higher reality behind the mundane one? What if your mind could suddenly merge with a universal cosmic consciousness? What if you unexpectedly started to understand the unknowable, the ineffable, the thing-in-itself, the noumenon? Or, what if you started to receive knowledge directly from sources outside of space and time? What if God (or the gods) began to engage you in a dialogue? Even more dramatic, what if you discovered the spark of God (or the gods) within yourself? Being absolutely certain, with every single fiber of your being, of the authenticity of such truths, how would you communicate this transcendent knowledge to your ignorant fellow human beings? How would you handle the crippling solitude of being the only person bestowed with such divine insights? How then, would you continue to lead your life? Would you commit yourself to a psychiatric institution with a self-diagnosed manic psychotic break? Or, would you start to source the knowledge through yourself and try to inspire others? Perhaps some inspiration can be found in the spoken words of Alan Watts, a philosopher, psychonaut, mystic, and interpreter of Eastern philosophy[2]:

> Some people get a glimpse that we are no longer this poor little stranger and afraid in a world it never made—but that you are this universe. And you are creating it at every moment.
>
> And you see, if you know that the I—in the sense of the person, the front, the ego—it really doesn't exist, then it won't go to your head too badly if you wake up and discover that you're god.

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[1] Adapted from https://en.wikipedia.org/wiki/Allegory_of_the_Cave, retrieved December 2, 2017.

[2] See http://www.alanwatts.com/ or https://soundcloud.com/gutzeit-945453634/elias-dore_gutzeit_1#t=12s, retrieved December 6, 2017.

1.1 At a Glance

There are various options of how one can proceed with reading this book. The *User Manual*, beginning on page xv, summarizes them. In the following, Sect. 1.1.1 gives a very brief outline of the entire content and Sect. 1.1.2 a compact chapter overview. Then, Sect. 1.2 provides a more detailed summary of each chapter. Finally, Sect. 1.3 offers a content map, giving an even more detailed overview of the covered terrain, by chapter and section.

1.1.1 A Very Short Outline of the Journey

The voyage you are about to embark upon is broken down into three separate legs:

1. Part I: Climbing to the summit of the island of knowledge.
2. Part II: The downfall and the boundaries of ignorance.
3. Part III: New frontiers on the horizon.

The story evolves around human knowledge generation and ignorance, the struggle to find an island of certainty in a fierce sea of uncertainty. In a nutshell, it is the adventure of the human mind's search to understand itself and the world it is inhabiting. In other words, the age-old questions "What is reality?", "What can I know?", and "Who am I?" are tackled once again. It is a long journey building on all the achievements and failures of the human mind. In essence, it is an adventure of science and philosophy.

After reading Part I, one should be greatly awed and humbled by our mind's profound ability to make sense of a world it woke up to one day. The relentless dedication, decisiveness, and perseverance of the humans pursuing the quest for knowledge should be a source of true inspiration to us. However, after finishing Part II this exhilaration should have turned into despair. The world has stopped making sense, and cracks appeared in the foundations of reality. The very notion of certainty is in jeopardy. In the words of Albert Einstein (Einstein 1949, p. 45):

> It was as if the ground had been pulled out from under one, with no firm foundation to be seen anywhere upon which one could have built.

Reality, and its material source, fractures. Time and causality lose their meaning. Our own identity is demystified. The self is a hallucination and free will an illusion. The inner world we experience is precariously detached from the outer world. The darkness of existential angst momentarily settles upon the human psyche.

Here is where Part III provides comfort and shines a novel light onto the world. A new horizon emerges, offering a new kind of knowledge—a novel understanding of ourselves and the world, that potentially can disentangle some of the mystery of being. However, in order to accept this new chapter in the history of human knowledge, a lot of conceptual baggage needs to be thrown overboard. The reader is invited to entertain notions which might feel alien and heretical—invited to rethink the most basic assumptions and most cherished beliefs about existence. The new gospel is simple: Information is the essence of reality—the substrate of existence. It has an inner aspect giving rise to subjective experience (consciousness) and an outer aspect from which the tapestry of reality is woven. The implications and conclusions of this new paradigm are truly outlandish. Here the inquisitive reader can directly proceed to the last chapter, summarizing the journey and the new insights.

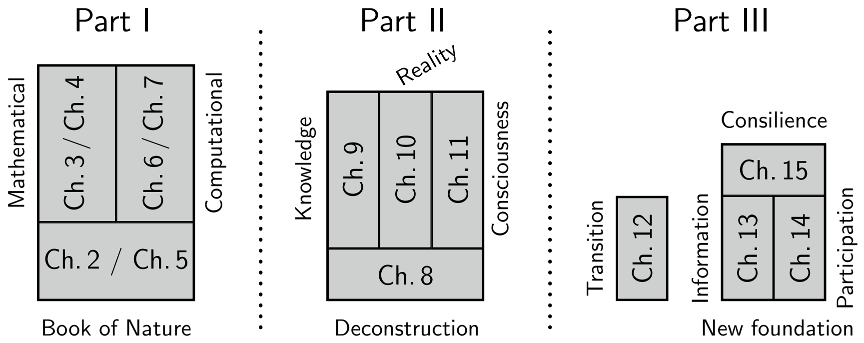
1.1.2 Chapter Overview

The adventure begins with the understanding that the Book of Nature is written in the language of mathematics. It is uncovered, how an act of translation enables the human mind to generate knowledge of the world (Chap. 2). This mechanism is elucidated by the notion of symmetry, allowing a large chunk of theoretical physics to be discovered (Chaps. 3 and 4). Analyzing the structure of knowledge uncovers a classification scheme, which orders human knowledge generation—from the understanding of fundamental processes of the universe to the complexity surrounding us (Chap. 5). A detailed description of the study of complex systems is given (Chap. 6) and its applications to finance and economics (Chap. 7).

Up to now, Part I has chronicled the success story of the human mind scaling the mountain of knowledge. Despite coming close to the summit, the apparently inevitable downfall is encountered in Part II. All the challenges vexing the human mind are outlined in Chap. 8, setting the stage for a detailed analysis in the following chapters. Chapter 9 asks, “What can I know?” Any attempts at answering this question touch upon the philosophy of science, the crisis of modern science, and the limitations of mathematics. “What is reality?” uncovers our vast ignorance of the nature our universe. Our theories fall apart, revealing a fragmented and incoherent landscape of knowledge. We are unaware of a majority of the content of reality. Moreover, under close inspection, time and matter loose their tangibility (Chap. 10). Finally, “What am I?” exposes the greatest enigma. How can a brain create subjective experiences and why? Our brains are forever locked in a dark and silent skull, constructing virtual reality simulations. The conscious mind is only a tiny island in the large archipelago of subconscious processes. Memories are also unreliable fabrications of the mind. Even the notion of an identity and free will is an illusion (Chap. 11). Part II exposes the futility and incomprehensibility of existence—the universe appears pointless, callous, cruel, and cynical. This has ramifications for society as a whole (Chap. 12).

Finally, Part III offers a novel understanding of the nature of consciousness and reality. A new paradigm emerges, built upon an information-theoretic ontology (Chap. 13). Moreover, this knowledge uncovers an even deeper reality: a participatory universe, where there exists a kinship between the mind and the cosmos (Chap. 14). In effect, the prevailing materialistic and reductionistic scientific worldview has been replaced by a novel understanding of existence, incorporating the human mind at its very core. In conclusion, Chap. 15 summarizes the entire journey and catches a glimpse of the new horizon.

A schematic overview of the content of this book is provided in the following illustration:



- Part I: The gift of knowledge. A story of how the human mind was able to unlock the workings of the universe in order to manipulate physical reality, creating technology.
  - Chapter 2: Mathematics is the language of the universe. Human knowledge generation hinges on an act of translation.
  - Chapter 3: How the notion of symmetry is one of the most powerful concepts in physics.
  - Chapter 4: Symmetry allows physics to be unified.
  - Chapter 5: A classification of knowledge. Understanding the universe with equations is only the beginning. Complexity can be tamed with algorithms running in computers.
  - Chapter 6: The new science of complexity.
  - Chapter 7: Applied complexity. Finance and economics in a new light.
- Part II: Ignorance and the limits to knowledge. The self-critique of the modern mind. The growing cracks in the edifice of the current materialistic and reductionistic scientific worldview.
  - Chapter 8: The problem of certainty. Age-old questions of existence.
  - Chapter 9: The crisis of modern science, or "What can I Know?"
  - Chapter 10: The true and uncanny nature of reality.
  - Chapter 11: The reality of subjective consciousness, or "What am I?"

- Part III: New horizons. "Could there be something we don't yet know about ourselves and the universe, the knowledge of which could change everything?"
  - Chapter 12: We live in the age of post truth, where "my ignorance is as good as your knowledge." A glimmer appears on the horizon.
  - Chapter 13: An information ontology is discovered, where information is physical and the foundation of reality.
  - Chapter 14: A participatory ontology is outlined, where the human mind and the cosmos share a kinship.
  - Chapter 15: The final summary and conclusion, glimpsing a new horizon.
- Epilogue.

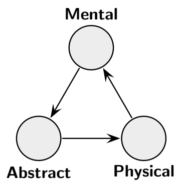
1.2 The Story in a Nutshell

1.2.1 Part I: Climbing to the Summit

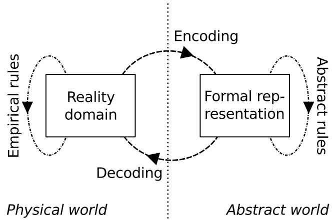
Chapter 2: In Search of the Book of Nature

The history and hallmarks of human knowledge generation are discussed. An old metaphor describing the intelligibility of the world was found in the idea of the Book of Nature, where the universe can be read for knowledge and understanding. It was realized a long time ago that the Book of Nature is written in the language of mathematics.

Philosophers and scientists have argued that this metaphor encapsulates the interplay of three distinct worlds: the abstract Platonic realm of mathematics, external physical reality, and the human mind harboring mental states. This is shown in Fig. 2.2 on Page 58:



In effect, the Book of Nature can now be rephrased with modern concepts. Quintessentially, knowledge generation is an act of translation in the human mind. Aspects of the physical world are encoded as formal representations, like mathematical equations. These abstractions inhabit an abstract world of their own and follow their own rules of consistency. The human mind can access and manipulate the formal representations in the abstract world and decode them. This happens by predicting behaviors of the physical world, from abstract insights, which then can be empirically tested. This knowledge generation process is illustrated in Fig. 2.1 on Page 45:



Modern examples of this mechanism are discussed, starting with Isaac Newton's prototypical physical theory of classical mechanics. The interplay between mathematics and physics is examined and some aspects of mathematics analyzed. Several biographies are presented.

Philosophers and insightful scientists realized that this intimate interplay of the human mind with the workings of the universe poses mystifying challenges. In essence, three worlds are interacting: the physical, the mental, and the abstract. More sober scientists have declared "Shut up and calculate!" and circumvent such philosophical artifacts by focusing on the formalism.

On a technical note, the contents of this and the two following chapters are necessarily laden with mathematical symbolism. In order for the non-mathematical reader to still be able to follow the narrative, a precaution is taken. All of the more involved equations are clearly delimited, allowing the reader to avoid these abstract pitfalls. To this aim, special attributed tags are introduced, denoted by $\{\oiint \ldots \oiint\}$, which encapsulate the mathematical formalism. See also the *User Manual* on Page xv.

Chapter 3: The Semantics of Symmetry, Invariance, and Structure

A case study of how the notion of symmetry underpins modern physics. The intuitive idea of symmetry is formalized as a mathematical concept (group theory). Now it becomes an ideal vessel for encoding aspects of the physical world in abstract terms, illustrating the act of knowledge generation via translation.

Symmetry can be intuitive and elusive at the same time. Obvious and straightforward notions related to it can result in deep mathematical structures being uncovered, which mirror the workings of the universe. Namely, invariance, the concept that the manipulations of a system leave it unchanged. For instance, rotating an unmarked cube by 90° along any of its three axes leaves it indistinguishable from its original orientation. The cube is invariant under such transformations. Requiring that the outcome of a physical experiment should not depend on the time and location it is performed at can be expressed mathematically as invariance. In detail, the invariance of physical theories under changes in space and time result in conservation laws, specifically the conservation of momentum and energy in the universe. This theme goes to the heart of theoretical physics (Emmy Noether's theorem). The fundamental symmetries of space-time are encoded as a mathematical group and give rise to fundamental laws of nature. Moreover, physical particles, so elusive to our senses and intuition, transform according to yet another symmetry group, giving us an analytical lever to manipulate them. Finally, the very relation of space and time, encoded in a transformation, results in a maximum speed of causality, which is confined to be the speed of light by invariance.

In order to understand the importance of group theory in physics, the mathematics of geometry are introduced. Classical mechanics is rediscovered in the generalized formalism of the Euler–Lagrange equation. Also, elements from quantum theory, quantum field theory, philosophy, and history are discussed throughout the chapter.

The notion of conserved quantities has an ancient history in Greek philosophy (Parmenides, Heraclitus, Anaximander, Leucippus, and Democritus). It is related to the concept that nothing can come from nothing and that reality is composed of indivisible, indestructible, and eternal atoms. A similar concept of atoms is found in the Indian religion of Jainism, a radically non-violent tradition which shares in its cosmology many of the elements of pre-Socratic Greek philosophies.

Chapter 4: The Unification Power of Symmetry

Inspired by the success of Albert Einstein's general relativity, Hermann Weyl introduced a new kind of symmetry in 1918. It was called gauge symmetry and the corresponding notion of gauge invariance lead to the discovery of gauge theory, a pivotal achievement in theoretical physics. This would then revolutionize the understanding of all three non-gravitational forces in the universe. In essence, the discovery of a novel local type of symmetry would allow the standard model of particle physics to be formulated, decades later. Going beyond this edifice, modern unification efforts in physics extend those notions of symmetry in what is know as superstring theory.

The principle of covariance was one of Einstein's main ingredients for the theory of general relativity. It rests on a benign assumption of symmetry: the contents of a physical theory should not depend on the choice of coordinates required to express and compute the theory. In other words, physical laws are invariant under coordinate transformations. This commonsensical requirement is one of the two cornerstones of general relativity. The second one being the principle of equivalence: it is impossible to distinguish the force of gravity from the effects of acceleration.

The history of gauge theory was a meandering story that led to the uncovering of a new layer of reality below the phenomena of electromagnetism (electromagnetic potential, Aharonov–Bohm effect). Theories were formulated, which lay dormant for years, and nearly forgotten, before they came to prominence and paved the way to a new understanding of the universe (Yang-Mills theory). Indeed, many theoretical hurdles had to be overcome before a successful marriage of gauge theory and quantum field theory culminated in the standard model of particle physics. For instance, the Higgs mechanism, a mathematical machinery designed to generate mass terms in the theory via spontaneous symmetry breaking.

However, the standard model marks only the beginning of a unified theory. The Holy Grail of physics is seen as the unification of the standard model with gravity, in a overarching theory of quantum gravity. Physicists attempts to reconcile their fragmented theories has led to many esoteric postulations about the nature of reality. For instance, the existence of unseen extra spatial dimensions, rendering our universe a higher-dimensional behemoth. An idea first introduced by Theodor Kaluza and Oskar Klein, it saw its coming of age in ten-dimensional and 26-dimensional variants of superstring theory. Moreover, the adjective "super" in superstring theory refers to yet another novel symmetry attached to nature, relating bosons (the force-carrying particles) to fermions (the matter particles: quarks and leptons).

Whole new branches of mathematics (algebra, topology, geometry, and group theory) were forged in order to reconcile the splintered landscape of theoretical physics in a unified theory. The resulting attempts culminated in M-theory, the eleven-dimensional unification of the five existing ten-dimensional superstring theories, approximated by the theory of supergravity at low energies.

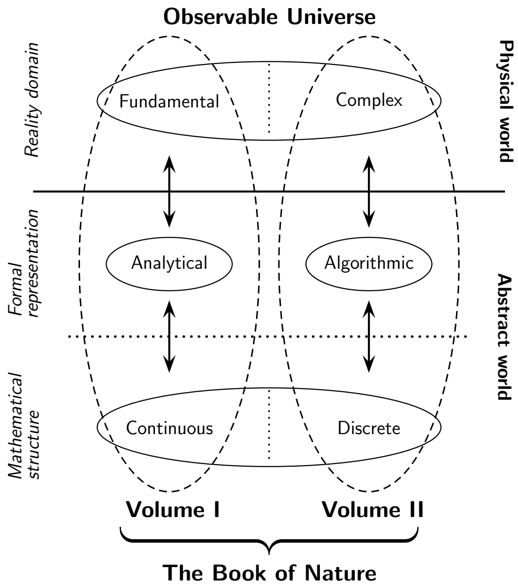
Despite the enormous experimental success of the standard model, string/M-theory has to this day produced no (falsifiable) predictions. Indeed, Einstein already failed at formulating a unified field theory in his final years. Being arguably the most influential physicist (the Nobel Prize-winning photoelectric effect, special and general relativity), he struggled with the reality and implications of quantum mechanics and spent the years from 1928 to his death in 1955 grappling with his unified field theory.

A brief detour through the history of quantum mechanics and quantum information is included.

Chapter 5: The Two Volumes of the Book of Nature

The age-old dream that mathematics represents the blueprint for reality has become fulfilled: the Book of Nature is intelligible to the human mind. Consider the notion of symmetry. Expressed mathematically, it is foundational to physics and runs through its fabric as a common thread. This is an example of how knowledge generation is the result of an act of translation: the human mind encodes reality domains into formal representations and is able to make predictions about the workings of the universe (decoding).

As it happens, this way of categorizing knowledge is only the beginning. In other words, what has been called the Book of Nature is in fact only Volume I in a greater series. Chapter 5 attempts to outline this Weltanschauung. The resulting picture is captured in Fig. 5.8 on Page 171:



It rests on three classifications which are introduced and elucidated in detail:

1. The distinct reality domains: fundamental/complex.
2. The nature of the formal representation: analytical/algorithmic.
3. The structure of mathematics: continuous/discrete.

From this, two dichotomies of understanding emerge:

1. The *fundamental-analytical*, found in Volume I of the Book of Nature.
2. The *complex-algorithmic*, describing the recently discovered second volume.

In a nutshell:

VOLUME I The *fundamental* reality domains (mostly pertaining to the quantum and cosmological levels of reality) are made accessible to the mind via *analytical* formal representations (equations). This relates to physical science.

VOLUME II Real-world *complexity* (from inanimate self-organizing structure formation to emergent phenomena like life and consciousness) is encoded via *algorithmic* formalizations (algorithms and simulations running in computers, they themselves being a gift found in Volume I). This relates to complexity science.

Following this categorization of human knowledge, the success, paradigms, and limitations of fundamental processes and complex systems are outlined. Most crucially, both volumes of the Book of Nature rely on two specific miraculous circumstance for their success:

VOLUME I The power of human formal thought systems: "The unreasonable effectiveness of mathematics in the natural sciences" (Eugene Wigner). See Sect. 9.2.1.

VOLUME II Complexity arises from simplicity: "Some of the very simplest programs that I looked at had behavior that was as complex as anything I had ever seen. It took me more than a decade to come to terms with this result, and to realize just how fundamental and far-reaching its consequences are" (Stephen Wolfram). See Sect. 5.2.2.

In this context, chaos theory, fractals, agent-based simulations, and complex networks are discussed.

Relating to historical circumstances, this part of the journey takes the reader to the new science of networks, starting with sociological experiments ("the strength of weak ties", "six degrees of separation") and culminating in the discovery of small-world and scale-free networks, appearing everywhere in nature and human affairs, at the turn of the millennium.

Contemplating the two dichotomies of fundamental-analytical and complex-algorithmic knowledge generation, the following question arises. What about the two other possible modes of understanding? Namely, the fundamental-algorithmic and complex-analytical categorizations. It is discussed how these two play a minor role in the Book of Nature.

Finally, the deepest layer in Fig. 5.8 is discussed, relating to the structure of the mathematics underlying the two dichotomies (i.e., Volume I and II). In this sense, mathematics is the ultimate unifying theme of all human knowledge of the universe. Specifically, mathematics can be delimited into two subject matters: the continuous and the discrete. This schism has its philosophical roots in ancient Greece and is also related to the conflicting notions of the finite and infinite. The history of continuous mathematics is recalled, starting in Greece, moving through the Protestant Reformation and the Middle Ages, and ending today. In essence, the multifaceted mathematical tool of the derivative, a cornerstone of continuous mathematics, appears in all of physics.

Discrete mathematics, the antipode of the continuous, also has an ancient history. However, the concept only really came to prominence in the context of information theory and computation. One specific area of discrete mathematics emerged as the cornerstone for the description of complex systems: graph theory (developed by Leonard Euler, one of the most prolific mathematicians of all times). Similar to the derivative playing a prominent role in Volume I of the Book of Nature, the graph is an essential formal concept, encoding complex systems in Volume II.

Chapter 6: Volume II: The Simplicity of Complexity

So, what is written in Volume II of the Book of Nature? What exactly is complexity science? And how does the science of simple rules work?

Complexity theory is not a single discipline, but an amalgamation of different fields of study. It has a long history, starting in the 1960s with cybernetics. Other influences came from systems theory, artificial intelligence research, non-linear dynamics, fractal geometry, and chaos theory. Today, a major discipline of complexity science is complex systems theory. A complex system is comprised of many interacting elements. Here the relevance of simple rules of interactions becomes visible. Moreover, a complex system can be formally represented as a complex network.

From a philosophical perspective, structural realism argues that, in fact, only relations are relevant. In other words, the network of interactions is key. This has, however, been contested by some philosophers of complexity, who favor poststructuralism, a variant of postmodernism. In a nutshell, complexity science invites a systemic and holistic paradigm, abandoning the prevalent, and thus far successful, reductionist thinking. It is characterized by decentralization and a bottom-up approach to the understanding of reality.

Complex networks are ubiquitous and found in many different domains, from the living to the non-living. The research on complex networks has exploded in the last decades. This development happened hand in hand with the emergence of data science, providing the empirical foundations. Complex network analysis can be applied at different levels of resolution and detail.

A scaling law describes a simple functional relationship. A change in input results in a proportional change in output. Albeit being an elementary mathematical expression, scaling laws describe a vast amount of natural phenomena. In effect, scaling laws can be understood as laws of nature describing complex systems. There exist four types of scaling laws. Allometric scaling laws describe how the properties of living organisms change with size. For instance, heavier animals live longer and have slower heart-rates than lighter ones. However, the actual number of heart-beats per lifetime is constant across mammals. Then, scaling-law distributions characterize many phenomena, in contrast to a normal distribution. In essence, most members of a population are irrelevant in scaling-law distributions, whereas a select few are disproportionately important. There is no preferred scale, resulting in scale-invariant behavior. A myriad of phenomena obey such a distribution. Furthermore, scale-free networks incorporate scaling laws in their topology. Again, many such networks can be found in nature. Finally, cumulative scaling-law relations describe how properties appearing in time-series are related. Especially, in financial data. Historically, scaling laws are associated with the Pareto principle, Zipf's law, and Benford's law.

Chapter 7: Applied Complexity: Finance and Economics in a New Light

In the past 500 years, humanity has created a single world order based on the interplay of science and technology, industry and economics, and military interests. In essence, our species has merged into one global network of human activity. The understanding of the structure and functioning of this super-system is perhaps the single most important goal to ensure equitable future prosperity, in economic and ecological terms.

The mathematization of finance began in the year 1900 and involved some eminent physicists. It was centered around the concept of a stochastic process. 97 years—and many equations—later, the Nobel Memorial Prize in economic sciences was awarded for the Black-Scholes model, leading to a financial crisis and bank bailouts. At the center of this mathematical evolution stood (and stands) the quantitative analyst, often recruited from physics.

Perhaps the single most influential ideological influence came from the Chicago School, promoting the neoclassical brand of economic thought, giving birth to the doctrine of neoliberalism around 1980. Today, neoliberalism is the world's dominant economic paradigm, favoring decentralization and privatization. Many economists have criticized this concoction of mathematical opacity, laissez-faire economics, belief in efficient markets and human rationality, lack of empirical foundation, and missing governmental oversight as the root cause of the housing bubble, which turned into a global financial crisis, and eventually a sovereign debt crisis.

In contrast, complexity science offers a new paradigm to understand financial and economic systems. Yet again, networks of interaction are the the heart of the solution. Complex dynamic systems, based on empirical observations, including feedback loops and non-linear behavior, replace idealized and arcane mathematical wizardry, based on very stringent assumptions. One specific approach employs agent-based models to decode financial markets. Another one utilizes centrality measures in the global ownership network to estimate corporate power.

The history of finance and economics is closely tied to the rise of European imperialism. Capitalism is based on the trust in the future, allowing for progress. One vision of this, advocated by neoliberalism, sees unapologetic and unrestrained human self-interest at the core of the engine generating collective wealth. However, greed and fraud are very seductive. They promise short-term enrichment but threaten the long-term formation of an equitable and sustainable society, living in ecological balance with the biosphere supporting life on Earth. Indeed, the banking sector has a notoriously bad reputation when it comes to financial scandals. Greed and fraud appear to be a systemic affliction of the profession. Buddhism, at its core, identifies insatiable greed as one of the main causes of human suffering. Happiness economics appears to agree. Moreover, confronted with one's own death, a life spent with meaning and social interactions appears to outmatch a life solely filled with material wealth.[3] In stark contrast, evolutionary (and mathematical) biologists see cooperation and altruism as the successful templates and driving forces of sustainable collective well-being, outperforming selfishness and egoism.

Today, eminent economists identify the accelerated increase in global inequality as one of the greatest threats to future prosperity—economic and ecological. Even some billionaires agree that they profit from a system which is not sustainable. Looking into the future, a paradigm change could be underway, with the potential to disrupt all financial and economic interactions. It is initiated by a change in the architecture of our man-made systems. A new blueprint, favoring decentralization, is beginning to replace the predominant design pattern: the tribal pyramid of power. Motivated by insights from complexity science, these new systems have the potential to exhibit self-correcting, sustainable, and resilient behavior. In detail, the emergence of a distributed, fail-proof, and tamper-proof public ledger, enforcing transparency, security, and auditability by design, is driving the revolution. Distributed ledger technology is the great innovation at the heart of the nascent rise of Bitcoin.

[3]Based on statements of US citizens requiring palliative care.

1.2.2 *Part II: The Downfall*

Chapter 8: A Brief Story of Success: The Manifestation of Knowledge and the Hydra of Ignorance

The quest to comprehend the world we live in has taken the human mind on a true odyssey—it is a spectacularly successful story of knowledge generation. Ignorance is dispelled and the unveiling of knowledge is driving the acceleration of modern technological advances. All seems comprehended and we are tempted to close the Book of Nature with satisfaction. However, in an astonishing, unexpected, and momentous plot twist, the anticipated ending of this narrative opens up Pandora's box of existential dilemmas, ontological paradoxes, and epistemic uncertainty. Ominous clouds appear on the horizon.

First of all, uncertainty viciously raises its head—again. Throughout the history of thought, uncertainty could never be banished. The most developed theory of ignorance in modern philosophy is that of Immanuel Kant. His epochal classic *Critique of Pure Reason* argues that we can only ever know things as they appear to us and never the things as they are in themselves. Furthermore, the question of "Why is there something rather than nothing?" truly represent one of the hardest enigmas of existence. Finally, all the cosmic coincidences which had to occur in the evolution of the universe for this exact moment in time to transpire raises more mind-numbing challenges. We are confronted with issues relating to teleology, entelechy, creationism, and the notion of a simulated reality.

In summary, the core enigmas of existence can be phrased as three questions:

1. What can I know? (Chap. 9)
2. What is reality? (Chap. 10)
3. What is consciousness? (Chap. 11)

And so the grand narrative of the world continues to unfold, albeit in a very unexpected direction.

Chapter 9: Philosophy and Science: What Can I Know?

The spectacular display of human technological prowess seen today is a testimony to the success of the human mind in deciphering the workings of the universe. Science works! But how exactly and why? The philosophy of science outlines the failure of the attempts to explain, structure, and justify science. Beginning with logical empiricism and critical rationalism, the efforts to systematize the scientific method based on common sense failed. Inductive and deductive reasoning suffer from conceptual problems. Thomas Kuhn influentially argued that science progresses by virtue of sudden, unforeseeable disruptions, called paradigm shifts. Science is not a linear accumulation of knowledge and it is greatly influenced by socio-cultural aspects and the idiosyncratic preferences of scientists. Abandoning the hope for a single universal truth, postmodernism focuses on ambiguity and diversity. Indeed, modern theoretical physics appears to have reached a threshold, where meaning, clarity, and understanding are in jeopardy. Then, constructivism argues, once more, that social and cultural conditions shape knowledge. Finally, relativism appears to undermine any structured knowledge of the world. The influential and controversial philosopher of science, Paul Feyerabend, continually challenged the scientific establishment. He was dubbed "the worst enemy of science." Perhaps Feyerabend was profoundly misunderstood, as he wholeheartedly embraced science but rejected the claims of its rational and structured nature.

Looking at the evolution of science, the emergence of modern science marks the begin of a deep crisis, beginning in 1901. Nearly every postulate of classical science was overthrown by the new physics and replaced with bizarre new concepts, from the elusive quantum fluctuations to the fabric of space-time. The aftershocks of this fundamental transformation still echo to this day. Quantum theory represents one of the greatest conceptual enigmas ever to have challenged the human mind. Perhaps even more pressing is then the question relating to the comprehensibility of the universe. Why can the mind unlock the secrets of reality? This question continues to baffle many great scientists and philosophers. Finally, is the end of science in sight? Is science being undermined by the all-too-human nature of scientists? Is scientific progress grinding to a halt? Paradoxically, as each question about the workings of the universe gets answered, new and harder questions emerges. An observation many scientists agree upon. In effect, ever more knowledge is uncovered, but it only represent an infinitesimal progress in understanding. If asked, some scientists will admit to these shortcomings: uncertainty and ignorance are inherent and ubiquitous.

Finally, even mathematics, allegedly the pristine body of knowledge containing aesthetic and timeless truths, turns out to be severely limited. Not only is mathematics incomplete (Kurt Gödel's famous theorems) but it is fundamentally plagued by randomness. The mathematician proving this statement, thus continuing Gödel's haunting legacy, radically compared mathematics to zoology. Indeed, hyper-abstract modern mathematics also suffers from the loss of meaning, clarity, and understanding. Such insights do not bolster the confidence in any enterprise relying on mathematics.

In the final analysis, it seems as though the edifice of human knowledge is a shifting, ad hoc, and fragmented structure, lacking any clear foundation and overarching and unifying context. Mathematics and science appear to be true by accident.

Chapter 10: Ontological Enigmas: What is the True Nature of Reality?

Physics has reached a dead end. All the successful theories describing the intimate workings of reality turn out to be incomplete and incompatible fragments of knowledge floating in the void of the unknown. Under closer inspection, the impressive theories of the universe unravel. The whole monumental structure of knowledge falls apart like a house of cards. We are left with a frustratingly long list of unsolved mysteries—from the bizarre quantum level of reality to the vast cosmos, of which 95% of its content is still unknown to the human observer. Moreover, the most accurate theories fail miserably at the borders of their domain of comfort. Even worse, it turns out that the human mind has cultivated the wrong intuitions about reality. But perhaps the hardest blow comes from quantum physics. The realm of the very small displays behaviors which transcend our conceptions of reality—even after over a century of grappling with its interpretation. So too does the cosmic fabric. Space, time, and matter are found to be ineffable qualities of a formerly comprehensible universe. Determinism, causality, materialism, the past and the future, definiteness, and an objective and a mind-independent world seem like the dreams of an unattainable paradise. Ironically, the mind is allowed to transform the knowledge fragments it is given into powerful technology, but it is not permitted to peak behind the curtains of reality. The ontology of reality is not comprehensible to the human mind. Our best efforts at extending our knowledge—in the guise of a theory of quantum gravity—have all been unsuccessful. The Book of Nature turns out to be an incomplete translation. The original appears to be written in an alien language, unintelligible to us, hiding vastly greater knowledge from the our mind. It is then perhaps no wonder that some great physicists became enticed by mysticism and spirituality at the end of their lives.

Chapter 11: Subjective Consciousness: What am I?

Philosophers have been debating consciousness since the birth of philosophy. Until recently, the very notion of consciousness was excluded from any scientific investigation. Today, philosophers of the mind, neuroscientists, and cognitive scientist agree that consciousness is one of the biggest enigmas. On the one hand it is so intimately familiar to us. Indeed, we all appear to be self-determined consciousness—a self with free will. On the other hand, linking the ethereal mind to tangible physical processes in the brain is a hard problem. Solutions come form an outright denial of the reality of consciousness to viewing reality as goal-driven and caused by a transcendent agent. Something has to give. The inner world we experience is precariously detached from the outer world.

Insights from neuroscience speak of the limited capabilities of the conscious mind. Consciousness appears to be a narrator reacting in hindsight to decisions made in the vast subconscious mind. The perception of the outer world is based on a constructed simulation, rather than reflecting objective truths. The sense of self is also an intricate construct of the mind which can be damaged. Memories are not archived but are constructed on the fly. Beliefs, morals, and ethics have a biochemical component and also depend on the biologically evolved "hardwiring" in the brain. Human behavior is demonstrably irrational and we are blind to a huge number of cognitive biases. We can be easily be manipulated without ever knowing. Then, our brains and minds can fall apart. A dramatic number of psychopathological disorders have been documented. Sometimes a brain trauma unlocks genius traits. Split-brain patients experience their unified self divide into two separate streams of independent consciousnesses.

The notion of free will appears highly problematic. From quantum mechanics we get two radically opposing options: either there is no free will in the universe or everything, including elementary particles, has free will. Neuroscientific experiments demonstrate the lag between the time a subconscious decision is made and the time the conscious narrator is informed about the decision.

These are today's challenges arising at the borders of knowledge, enigmas that are mostly swept under the carpet in a pragmatic attempt to conduct business as usual.

We face a gloomy dichotomy: the emergence of an astonishing body of knowledge—accurately decoding the workings of the physical world and fostering technological progress at breathtaking speed—is eclipsed by paradoxes, ambiguity, and incoherence. The true nature of reality is as elusive and mysterious as ever, we are missing the foundations and cohesion of science, and the problem of subjective experience dramatically exposes our profound ignorance. Is this a world doomed by uncertainty? Do we really live in a cynical universe, which reveals itself to the human mind just as far as to awaken the false hope in its comprehensibility and then leaves us forever in a state of epistemic and ontic nihilism? Was the Book of Nature simply a grand and elaborate farce?

Perhaps things are not what they appear to be. Maybe there is something we don't yet know about ourselves and the universe, the knowledge of which could change everything.

1.2.3 Part III: A New Horizon

Chapter 12: The Age of Post-Truth

The human mind lost all guidance form science and philosophy. An existential threat emerged, relating to the fundamentally incomprehensible nature of reality and consciousness. We are left with amazing technology, which we unfortunately and astonishingly keep utilizing to destroy the entire biosphere sustaining all life on Earth. Untethered, ignorance and anti-intellectualism abounds. Conspiracy theories are popular across a wide demographic. Conflicting beliefs result in a gridlock that is paralyzing our world on at every level. Sociopolitical, cultural, theological, philosophical, and scientific wars are waged.

But perhaps things are not as bad as they appear. We are slowly seeing the emergence of a new age. We have the first blueprints for decentralized economic interactions with the potential for collective intelligence—adaptability, resilience, and sustainability. Overall, the universe appears to be guided by an invisible force driving it to ever higher levels of self-organized complexity.

The voices presented in this book are intended to help this malaise. Motivated by scientific utilitarianism and radical open-mindedness, we are invited to rethink all our assumptions about reality and consciousness. A new horizon emerges, offering a firm foundation for existence. In the following chapters, the notions of information, consciousness, and reality will be braided into a novel unified fabric of existence. This is the final quest of the human mind: facing its own existence.

Chapter 13: A Universe Built of Information

We are currently witnessing a paradigm shift—perhaps the profoundest one to ever occur. The human mind is invited to sacrifice one of the most successful conceptions of understanding: the materialistic and reductionistic scientific worldview. This commonsensical idea, that at the core of reality lies a tangible essence from which the universe is constructed, no longer seems adequate. Guided by a small anomaly that was discovered in the 1970s, many branches of theoretical physics—including quantum gravity variants—and theoretical computer science are converging to uncover a novel unified picture. Information is physical. In other words, the seemingly intangible notion of information has clear physical consequences. For instance, information cannot be erased without the universe taking note (by registering an increase in entropy). Information theory, giving birth to the bit and our current digital computational revolution, is the first theory quantizing information.

Two great physicists and pioneers of modern theoretical physics—John Wheeler and Carl Friedrich von Weizsäcker—suspected that information was the ultimate nature of reality. "It from bit" popularizes this view. Indeed, the intractable conceptual issues related to the interpretations of quantum mechanics reemerge in a new light, once framed in a quantum-computational framework. Digital physics is a contemporary movement advocating this information-centric worldview. In essence, it argues that reality is inherently finite. Only in our formal mathematical theories do we encounter infinity. There is a fundamental limit—one bit per Planck area—to how much information can be stored anywhere in the universe.

Perhaps the most persuading hints come from the study of black holes. In 1974, Stephen Hawking discovered a property which challenged the laws of quantum mechanics. The crux was related to information loss. Today, this topic is still relevant and passionately debated. A key insight from string/M-theory entered the picture. As a result, all the cutting-edge theories speak of a holographic universe. Our familiar three-dimensional reality appears to be fictitious, emerging from the information encoded on a two-dimensional area. Moreover, space and time seem to be emergent properties arising from pure quantum entanglement. The final faction joining the struggle is theoretical computer science. Now it is as though computational complexity is driving the evolution of this information-theoretic reality. Given the potential of such an outlandish information-theoretic ontology, it comes as no surprise that some scholars have taken the next bold step. They suspect reality itself being a vast simulation.

The metaphor of the Book of Nature was a misguided thought. It seems that at the core of reality we find a computational engine which needs to be fed with information. The "Book of Nature" should be closer to a computational device in which the algorithms of reality are encoded. The static physical "pages" are replaced with a dynamic and fluid "display."

Chapter 14: The Consciousness of Reality

Information lies not only at the heart of objective reality, it is also intimately connected to subjective consciousness. In a final radical step, the information-theoretic paradigm shift unearths a participatory ontology. Consciousness is seen as primal and universal—a fundamental building block of the cosmos. A series of taboos is being broken and blind spots exposed, all inherently contained within the current materialistic and reductionistic scientific worldview. The question "Could there be something we don't yet know about ourselves and the universe, the knowledge of which could change everything?" is beginning to be answered. From subjectivity, spirituality, Eastern contemplative wisdom, shamanic traditions, psychedelics, and paranormal and psychic phenomena, the human mind is invited to reframe and reassess such notions. Such disruptive thinking within the Western mind goes back to Immanuel Kant. Contemporary scholars, like John Wheeler and Richard Tarnas, agree: we inhabit a participatory universe.

Hints are found in the emergence of non-localized and non-sentient intelligence, peer-reviewed studies in physics journals, and reports from psychonauts. In essence, many pioneers of quantum mechanics had always argued for such a participatory ontology. However, blinded by the current paradigm, which—confidently and with great certainty—deems what is heresy and not, certain elusive phenomena could have escaped our collective attention. While, for instance, infinite parallel universes, higher-dimensional space-time, and the denial of the existence of consciousness lie within the orthodoxy, the notion of a mind-matter link is off-limits—seemingly only espoused by the deluded, the fraudulent, or the incompetent. However, guided by the first formal approach to consciousness, based on information, new terrain is being charted. By welcoming the participatory ontology, reality and consciousness appear in a new light, offering novel understanding to help answer age-old questions of existence.

Chapter 15: Consilience

This is the last chapter in the human mind's quest for understanding. As it is itself a summary of the entire journey, the reader is invited to directly continue there. Final thoughts and outlooks are provided.

1.3 Chapter/Section Content Map

Part I: Climbing to the Summit

Chapter 2: In Search of the Book of Nature

The Book of Nature is an ancient metaphor describing humanities quest to understand the universe it inhabits. The philosophical notion is that nature is a book to be read for knowledge and understanding. Beginning with the scientific revolution over 300 years ago, it became apparent that the language of the Book of Nature is mathematics. Thus science can be understood as the challenge to capture the processes of nature within formal mathematical representations. This "unreasonable effectiveness of mathematics in the natural sciences" raises philosophical questions.

At the heart of this knowledge generation process lies an act of translation. Aspects of the physical world are encoded as formal representations. Once such abstract renderings are found, they can be manipulated by the human mind. Finally, new insights are decoded back into the physical world and their predictions can be experimentally tested.

– Section 2.1: A Modern Edition of the Book of Nature

Examples in the Book of Nature are presented: Newton's classical mechanics and electrodynamics, next to mathematical physics and new mathematics from physics.

– Section 2.2: Seeking Meaning

Philosophical implications are discussed. For instance, the existence of a Platonic realm of abstractions. This is placed within the context of the philosophy of mathematics. Bertrand Russel's paradox and Kurt Gödel's two incompleteness theorems, disrupting the foundations of mathematics, are encountered, next to some biographical elements from the lives of Srinivasa Ramanujan and Paul Erdős.
In essence, there exist three worlds : the physical world, accommodating the mental world of the human mind, which discovers or creates the abstract world of formal thought systems. The success of human knowledge generation rests on the peculiar fact that the abstract world mirrors the structures of the physical world. The questions of scientific realism and structural realism are touched.
Many scientists are, at best, uncomfortable when confronted with philosophical challenges. This sentiment finds its expression in the physicists rallying cry "Shut up and calculate!"

Chapter 3: The Semantics of Symmetry, Invariance, and Structure

The notion of symmetry , formally encoded as a principle of invariance, is singly one of the most powerful mathematical tools in unearthing novel and deep insights into the structure of the universe. Symmetry, expressed as invariance, essentially means that certain manipulations of a system leave it unchanged. This property can be encoded mathematically in the language of group theory. The tragic story of Évariste Galois is told, the founder of the theory.

– Section 3.1: Symmetry in Action: Conservation Laws

Another example in the Book of Nature is presented: conservation laws. Theses have an ancient history and a deep meaning in physics. In a nutshell, if a system possesses symmetry properties, then there exist quantities that are conserved in time. This profound theorem was proved by Emmy Noether. For instance, the invariance in time of a theory's symmetry (in plain words, the outcome of a physical experiment should not depend on the time it is performed at) results in the conservation of energy in the system it describes.
In order for this property to emerge, more mathematical abstractions are needed, in the guise of geometry. It is seen that classical mechanics can be rephrased in a geometric language introduced by Leonard Euler and Joseph-Louis Lagrange. A new quantity emerges in physics: the Lagrangian. It appears in many branches of theoretical physics (electromagnetism, the standard model of particle physics, and general relativity).
Returning to the notion of symmetry, Sophus Lie revolutionized its understanding, by introducing Lie groups and algebras. This allowed the purely mathematical concept of symmetry to enter physics, as groups can be represented by matrices that act as operators on quantum systems. Finally, some elements of quantum mechanics and quantum field theory are discussed and linked to representation theory.

– Section 3.2: Symmetry Manifested

Some concrete examples of the successful application of symmetry are described. By expecting the universe to be consistent and make sense to all observers, space and time have to be mixed. The resulting transformation, introduced by Hendrik Lorentz, encodes this peculiar behavior. Invariance under this symmetry results in the constant speed of light being the maximal speed for causality to propagate in the universe. Lorentz set the foundation for Albert Einstein to develop the theory of special relativity. This lead to the introduction of four-dimensional space-time, formally described by a Minkowski space.
The Lorentz transformation can be further formalized, yielding the Lorentz group. It encodes the fundamental symmetries of space and time. As a result, the behaviors of electromagnetism, special relativity, and all quantum fields are encoded via this formal representation. Finally, the Poincaré group extends the Lorentz group. All known physical particle states are described by this abstract mathematical framework, built from the notion of symmetry.

Chapter 4: The Unification Power of Symmetry

All the previously encountered instances of symmetry are expressions of global symmetry principles. In other words, these types of symmetry do not change at different locations in space-time. In 1918, a new local symmetry was introduced, leading to the development of gauge theory, a pivotal achievement in theoretical physics. This new type of symmetry would allow the standard model of particle physics to be formulated, decades later.

– Section 4.1: Back to Geometry: The Principle of Covariance

Einstein's theory of general relativity , describing gravity, rests on two assumptions. The principle of equivalence states that it is impossible to distinguish the force of gravity from the effects of acceleration. Einstein called this the "happiest thought of his life." The principle of covariance is the second ingredient. At first sight, it appears rather dull. The choice of the coordinates, required to make the elements of the theory computable, should not influence the content of the theory. In other words, physical laws are invariant under coordinate transformations. Unexpectedly, this leads to a deep mathematical formalism known as covariance. Specifically, the covariant derivative and Christoffel symbols.

– Section 4.2: The History of Gauge Theory

Inspired by the success of Einstein's general relativity, Hermann Weyl introduced a new kind of local symmetry in 1918. It was called gauge symmetry and the corresponding notion of invariance was introduced via the gauge-invariant derivative. Originally, Weyl applied his theory to electromagnetism. This attempt failed. However, with the developments of quantum mechanics, he successfully re-applied the ideas, leading to the formulation of gauge theory. Later on, this would lead to the development of Yang-Mills gauge theory.
Initially, quantum field theory and gauge theory were plagued by major problems. This "Dark Age" of theoretical physics was ended by the development of novel mathematical tools, collectively called renormalization.
A final hurdle in the formulation of the standard model of particle physics, a Yang-Mills gauge (quantum field) theory, was the problem of mass. The symmetries of the theory are only upheld if it describes massless particles. The final ingredient solving this issue is the Higgs mechanism of spontaneous symmetry breaking.

– Section 4.3: The Road to Unification

Unification is the Holy Grail of physics. It is the attempt to consolidate all physical theories in one single overarching framework. The "theory of everything" is the immodest name given to the postulated unified quantum field theory describing all known forces in the universe (the three non-gravitational ones unified in the standard model plus gravity). To this day, it is still an elusive dream.

An early successful attempt at unifying electromagnetism with gravity was found in Kaluza-Klein theory. This was achieved by moving to a five-dimensional space-time. A mechanism called compactification describes how our four-dimensional reality reemerges from the higher-dimensional theory.

A next attempt was string theory, an accidental discovery. It was originally formulated in a very different context unrelated to unification. At its core, the theory postulates that elementary particles and force carrying particles are not point-like (i.e., 1-dimensional) but extended 2-dimensional entities, akin to strings. For string theory to be mathematically consistent, it requires esoteric postulations about the nature of reality. For instance, the existence of unseen extra spatial dimensions, rendering our universe an eleven-dimensional structure. Moreover, a totally novel symmetry is proclaimed: supersymmetry. Now bosons (the force carrying particles) and fermions (the matter particles: quarks and leptons) are the two sides of the same coin. "String theory" is an abbreviation of superstring theory.

Historically, around 1980, string theory lay dormant. The candidate for a theory of everything was a higher-dimensional (quantum field) theory called supergravity. Physicists then believed that by the end of the century this would reveal the sought-for unified theory. After it was realized that supergravity could not fulfill its claims, string theory came to prominence in 1984. After this "first superstring revolution," five consistent string theories had been formulated in ten-dimensional space-time. The goal of unification appeared to move closer. Then, in 1995, Edward Witten showed that behind the five string theories lurked a unified eleven-dimensional theory, called M-theory, igniting the "second superstring revolution." Specifically, he showed that by moving to eleven dimensions, the physics described by this new theory corresponded to the five ten-dimensional string theories in limiting cases. Moreover, eleven-dimensional supergravity emerged as the low-energy limit of M-Theory.

Finally, the narrative returns to Einstein. After the spectacular success of his early years, he spent the last thirty years of his life chasing chimera. One futile endeavor he pursued to his deathbed was the failed development of a unified field theory. Einstein was also skeptical of the validity of quantum theory, despite his vital role in initiating the theory (his Nobel Prize-winning discovery of the photoelectric effect). He famously quipped that "the old one" (God) does not play dice, expressing his doubt of the probabilistic and indeterministic nature of quantum theory. A brief history of quantum mechanics and quantum information is presented: Max Planck's introduction of quanta in an act of despair and entanglement. To this day quantum theory remains undisputed.

– Section 4.4: Unification—The Holy Grail of Physics

This section concludes the current and previous chapters, which described the long journey from symmetry principles to the standard model of particle physics. Although a theory of everything—the unified theory of quantum gravity—appears as unattainable as ever, the standard model and general relativity, both based on symmetry principles, mark perhaps the greatest achievements of theoretical physics. Both theories have been tested to an extraordinary precision.

Chapter 5: The Two Volumes of the Book of Nature

It appears as though the Book of Nature has been found and deciphered. The universe has become intelligible to the human mind—from he subatomic world to vast cosmic scales. In essence, this understanding comes from translating reality domains into formal representations (encoding) and deriving predictions about the workings of the universe from them (decoding). However, this should only mark the beginning.
What has been called the Book of Nature up to now was a very specific translation: The *fundamental* reality domain (encapsulating the quantum and cosmological levels of reality) was encoded as an *analytical* formal representation (equations). A few decades ago, another translational process was discovered: *Complex* phenomena (from inanimate self-organizing structure formation to emergent phenomena like life and consciousness) are encoded via *algorithmic* formalizations (algorithms and simulations running in computers). In essence, the human mind has uncovered two volumes in a larger Book of Nature Series. For each volume a dichotomy has been unearthed, allowing the human mind to probe reality: the *fundamental-analytical* and the *complex-algorithmic*.

– Section 5.1: Volume I: Analytical Tools and Physical Science

Volume I of the Book of Nature is discussed. The success (seen in Chaps. 2–4), paradigms (symmetry and invariance), and limitations (from condensed matter physics to n-body problems and systems of interacting agents) of this approach are outlined. First hints of non-linearity and chaos theory emerge.

– Section 5.2: Volume II: Algorithmic Tools and Complex Systems

Volume II of the Book of Nature is introduced, allowing the human mind to tame complexity. This feat hinges on two novel paradigms. Complex systems are formalized as a set of agents and a set of interactions between the agents (P_1^c). Moreover, complexity is the result of simple rules of interaction (P_2^c).
(P_2^c) sets the stage for the new science of simple rules. This fact is as wondersome as Eugene Wigner's comments on the "reasonable effectiveness of mathematics in the natural sciences." One of the first scientists to glimpse the simplicity at the heart of complexity was Stephen Wolfram, a physicist, computer scientist, and entrepreneur. He set out to redefine all of science in *A New Kind of Science*. Chaos theory and fractals are discussed.
(P_1^c) spawned a new science of networks. Having its roots in sociology ("the strength of weak ties" and "six degrees of separation"), this research field exploded around the turn of the millennium. Driving the success was the discovery of two types of complex networks, found to be ubiquitous in nature (small-world and scale-free). This unlocked the understanding of complex systems found in socio-economical, biological, and physio-chemical domains. A new awareness of nature emerged, moving beyond reductionistic problem-solving and embracing a systems-based and holistic outlook.

– Section 5.3: The Profound Unifying Powers of Mathematics

The two classification schemes (reality domain vs. formal representation type) are extended by another level, relating to the structure of mathematics itself. From a bird's-eye perspective, mathematics splits into two subject matters: the continuous and the discrete.

The history of continuous mathematics is recounted. It begins in ancient Greece (Pythagoreans, Zeno, and Archimedes) and touches on the Protestant Reformation and the Jesuits, the persecution of Galileo Galilei, and the independent discovery of calculus by Isaac Newton and Gottfried Wilhelm Leibniz. Some of the philosophically relevant concepts include: the finite vs. the infinite, synechism, atomism, and monadism. A cornerstone of continuous mathematics is the derivative. This formal tool lies at the heart of the analytical machinery that is employed to represent fundamental aspects of the physical world. In essence, it drives all physical theories.

Although discrete mathematics is as old as humankind, it plays a minor role in today's mathematics curriculum. However, discrete mathematics is relevant for information theory and computation. Boolean algebra was a landmark development in logic. Claude Shannon implemented this for the first time using electronic components. He also introduced the notion of a bit—a binary digit—to represent digital information as 0 or 1. This is the basis of information theory, ultimately leading to the computer.

One specific area of discrete mathematics emerged as the cornerstone for the description of complex systems: graph theory. This was developed by Leonard Euler, one of the most prolific mathematicians, while he was thinking of how a walk through the city of Königsberg could be devised, that would cross each of the seven bridges only once.

Just as the derivative of continuous mathematics plays a crucial role in the *fundamental-complex* dichotomy (Volume I), graph theory from discrete mathematics allows complex systems, represented by networks, to be formalized as graphs, a cornerstone of the *complex-algorithmic* dichotomy (Volume II). In this sense, mathematics is the ultimate unifying theme of all human knowledge generation.

– Section 5.4: The Book of Nature Reopened

The dichotomies of *fundamental-analytical* and *complex-algorithmic* knowledge generation are only two possibilities out of four. It is discussed how the two other options—the fundamental-algorithmic and complex-analytical categorizations—play a minor role in the Book of Nature Series.

Chapter 6: Volume II: The Simplicity of Complexity

Finally, Volume II of the Book of Nature gives the mind insights into the workings of complexity. After decoding many aspects of the universe using equations, we now have the tools to tackle the complexity surrounding us and contained within us.

– Section 6.1: Reviewing the Book of Nature

A short reiteration of the concepts and ideas relating to the two volumes of the Book of Nature is given. Now, the simplicity of complexity is at the center of attention.

– Section 6.2: A Brief History of Complexity Thinking

The historical roots include cybernetics (1940s and 1950s), systems theory (1950s and 1960s), early artificial intelligence research (1950s and 1960s), and non-linear dynamics, fractal geometry and chaos theory (1960s to 1980s). One specific domain of complexity science is complex systems theory. A complex system is comprised of many interacting elements where a natural formal representation is found in a network. From a philosophical point of view, structural realism is pitted against post-structuralism.

– Section 6.3: Complex Network Theory

The core formal concept related to complex systems is discussed. Complex networks are ubiquitous in nature. Complex network analysis can be performed at different levels of resolution.

– Section 6.4: Laws of Nature in Complex Systems

Scaling laws can be understood as laws of nature describing complex systems. A scaling law is a basic polynomial functional relationship, where a relative change in input results in a proportional relative change in output, independent of the initial size of input. Scaling laws are scale-invariant and scaling-law relations characterize an immense number of natural processes. There exist four types: (1) allometric scaling laws (in biology), (2) scaling-law distributions (in contrast to a normal distribution), (3) scale-free networks (a scaling law found in the topology), and (4) cumulative relations of stochastic processes (relating to time series, especially financial ones). Historically, scaling laws go back to Galileo Galilei. The economist and sociologist Vilfredo Pareto found a scaling laws in the distribution of wealth in 1896, coining the Pareto principle (or 80-20 rule). Modern measures capturing inequality are the Lorenz curve and the Gini coefficient. Analyzing language, the linguist and philologist George Kingsley Zipf discovered a scaling law in the frequency of words. Finally, Benford's law describes a peculiar pattern found in random data.

Chapter 7: Applied Complexity: Finance and Economics in a New Light

Finance and economics are arguably the most important academic disciplines, as they have the greatest impact on all of life on Earth. Moreover, they are the fuel of progress, financing science and technology. Ironically, financial and economic systems are still badly understood and are affected by ideological entrenchment and dogma.

– Section 7.1: Terra Cognita

Adam Smith is the founder of modern economic thought. In 1776, he presented *An Inquiry into the Nature and Causes of the Wealth of Nations*. The mathematization of finance began in the year 1900, when Louis Bachelier introduced the notion of a stochastic process. This formalization of randomness was intertwined with the physics of the time and Max Planck and Albert Einstein played an important role. More mathematization included the Langevin and Fokker-Planck equations, next to Itô stochastic calculus and Benoît Mandelbrot's discovery of the fractal geometry of nature. In 1973, the Black-Scholes equation represented the pinnacle of this evolution and was rewarded with the Nobel Memorial Prize in economic sciences. The academics went on to found a hedge fund, which, after initial success, collapsed and resulted in bank bailouts. When physicists were faced with a dire academic job market in the early 1990s, they migrated to Wall Street. The quant, or quantitative analyst, came of age.

The global financial crisis was interpreted by many as exposing the failures of the predominant brand of economic thinking. Exponents from the "Chicago School" (going back to Milton Friedman and the Chilean free-market experiment), and neoclassical economics per se, were seen as accountable. However, the accused refused to accept the blame and saw others as responsible. One criticism addressed the mathematics, namely, the heavy, opaque, and archaic mathematical formalism utilized by neoclassical economics—not only due to its lack of empirical foundation, but also due to very stringent and unrealistic assumptions about human behavior and market dynamics. One example is the Gaussian copula, making the pricing of, formerly too complex, investments possible. For instance, the collateralized debt obligation (CDO) which, with credit default swaps (CDSs), fueled the subprime housing bubble which would ultimately trigger the financial crisis and in its wake, the sovereign debt crisis.

– Section 7.2: A Call to Arms

Many pundits blaming neoclassical economic theory see complexity theory as a potential savior. Pioneers of econophysics, like Jean-Philippe Bouchaud and Didier Sornette, have shown, with empirical evidence, that the complex dynamic behavior of markets defies the neoclassical paradigm. Moreover, complexity researchers have urged that the structure and dynamics of economic networks should be better understood and analyzed in-depth. Indeed, the global financial and economic networks are characterized by extreme interdependencies, where feedback loops and non-linear behavior are very relevant. Financial supervisors, regulators, and policymakers felt betrayed by the prevailing orthodoxy during the finical crisis and are looking for inputs from complexity science. Proposed reforms center around data-driven, interdisciplinary research, embracing complex networks, allowing for heterodox economics.

– Section 7.3: Complexity Finance and Economics

In detail, approaching economics and finance from a complexity perspective entails an empirical focus and the deployment of computer simulations. One specific algorithm-driven methodology is that of agent-based models. Agent-based simulations have revealed structures and mechanisms underlying the dynamics of real-world markets. In this paradigm, heterogeneous agents interact with each other, giving rise to emergent complexity. This is the polar opposite of the framework of representative agents in neoclassical economics, maximizing some utility. By employing network theory, the global ownership network can be analyzed in order to uncover the architecture of power. A network centrality measure is reinterpreted as corporate influence, linking the formal network to its domain of application.

– Section 7.4: The Past, Present, and Future of Economic Interactions

The cross-pollination of science and technology , industry and economics, and military interests led to the rise of European imperialism. The quest for profit and knowledge allowed Europe to establish a new global hegemony. When the Italian maritime explorer and navigator Christopher Columbus set sail, the Chinese, Muslims, and Indian domination soon faltered. Limited liability joint-stock companies, traded on stock exchanges, generated the profits for conquering the world.

However, there is a dark side associated with all this progress. Capitalism takes a heavy toll on the individual human psyche and the global ecosystem. Since the days of Adam Smith, it has been argued that, in fact, egoism is altruism. Self-interest is seen as a virtue. In contrast, evolutionary and mathematical biologists have long suspected cooperation and altruism to be the recipe for sustainable collective well-being. In Buddhism, greed is seen as one of the root causes of suffering—an insatiable hunger leaving one perpetually unsatisfied. Indeed, when humans are facing death, the accumulation of material wealth appears fruitless and hollow. Moreover, many people in Europe and the US experience their work life as a treadmill, devoid of meaning and gratification. Happiness economics analyzes how and when humans can gain spiritual satisfaction from material wealth. Fraud, next to greed, is another detrimental temptation. The banking industry has a long history of financial scandals, where markets were systematically manipulated for personal gain.

Keynesian economics, characterized by government spending during economic crisis, was a dominant economic ideology at the beginning of the 20th Century. In 1947, a small group of thinkers founded what later became to be knows as neoliberalism. Today, neoliberalism is the world's dominant economic paradigm, favoring deregulation and privatization. It is associated with unrestrained self-interest and laissez-faire economics and has influenced many different political movements. Neoliberalism has been spectacularly successful for a select few. Despite the spoils, insiders have reported on the unsavory culture which often prevails in places having the easiest access to wealth-accumulation. On a systemic level, the accelerating increase of global inequality is seen by many—economists and billionaires—as the key challenge facing humanity and threatening economic and ecological sustainability.

The design of most human systems is governed by a very specific architecture: the pyramid of power. This is a simple tribal hierarchy of concentrated influence. In contrast, the design patterns of nature, and hence complexity, are characterized by decentralization. The nascent rise of the crypto-currency Bitcoin has initiated a paradigm change in finance and economics by introducing the first decentralized blueprint of interaction. The innovation fueling crypto-currencies is the underlying data structure, called the blockchain. A blockchain is a decentralized, fail-proof, and tamper-proof public ledger, enforcing transparency, security, and auditability by design. The future of distributed ledger technology lies in its potential as a global "decentralized public compute utility," executing code representing any conceivable financial and economic interaction. Many expect a global disruption, similar to the introduction of the Internet.

Part II: The Downfall

Chapter 8: A Brief Story of Success: The Manifestation of Knowledge and the Hydra of Ignorance

The human mind's quest to comprehend the world is compared to the journey of the archetypal hero who ventures from the common world into a region of supernatural wonder and returns, bestowed with new powers. The discovery of the two volumes of the Book of Nature is reiterated. This manifestation of knowledge is driving the acceleration of technological advances and is having an unprecedented impact on how human societies organize themselves and interact with their environment. Indeed, we appear increasingly accustomed to this ongoing success.

– Section 8.1: Clouds on the Horizon

Regrettably, age-old questions, relating to existential dilemmas, ontological paradoxes, and epistemic uncertainty, continue to vex the human mind. Why does anything exist at all? Let alone life and consciousness? What can I learn, know, and understand about reality? Why can't uncertainty and ignorance be banished from the edifice of knowledge? In retrospect, looking at the 13.772-billion-year history of the universe, a plethora of cosmic coincidences conspired, bringing the universe's chaotic path-dependent evolution to this very moment in time.

– Section 8.2: The Core Enigmas of Existence

What can I know about the world (Chap. 9)? What is reality's fundamental nature (Chap. 10)? What is the true nature of consciousness (Chap. 11)?

Chapter 9: Philosophy and Science: What Can I Know?

Despite the spectacular success of the human mind in decoding reality and crafting technology, questions relating to the nature and structure of knowledge and science remain elusive.

– Section 9.1: The Philosophy of Science

This journey begins with history's first scientist in Greece. Two millennia later, the modern scientific method began to emerge, establishing experiments as the cornerstone of physical sciences. Logical empiricists and critical rationalists failed to found science on common sense notions—inductive and deductive reasoning suffer from conceptual problems.

Later, science was understood to undergo abrupt and unforeseeable paradigm changes in its evolution. The philosophies of postmodernism, constructivism, and relativism tried to come to terms with a reality which is ambiguous and tainted by every observer's belief system and socio-cultural context. Two examples are discussed, where postmodernism and theoretical physics have lost their meaning.

– Section 9.2: The Evolution of Science

At the same time as the human mind was extending its knowledge, the constricting limits of this knowledge became apparent. The discovery of quantum mechanics, special, and general relativity rocked the foundations of science. The classical notion of a comprehensible clockwork universe, independent of observers, was uprooted. The unsettling effects of this fundamental transformation are still felt today. The question of why the universe is comprehensible at all, emerges. Finally, some observers diagnosed the end of science. For every question science answers, new and harder questions emerge. In effect, while science produces ever more increments of knowledge, the understanding of the universe does not progress. Moreover, like every social human endeavor, academia can be plagued by blind obedience to authority, groupthink, corruption, and fraud. Scientists are put under relentless pressure to "publish or perish."

– Section 9.3: The Practitioners of Science

Usually, scientists aren't very vocal about their personal experiences of practicing science. The problem with knowing what beliefs scientists hold dear is that, by definition, this information is non-scientific. However, if asked, some sympathetic scientists will admit to the shortcomings discussed in this chapter—specifically, challenging notions of objectivity, truth, knowledge, and certainty relating to laws of nature, reality, and science. Uncertainty and ignorance are understood as being inherent and ubiquitous in the human condition.

– Section 9.4: The Limits of Mathematics

In a final blow, the limits of mathematics were exposed by Kurt Gödel and Gregory Chaitin. Building on the theorems of incompleteness, mathematicians discovered fundamental randomness at the heart of mathematics. All hopes of a consistent edifice of mathematics, built on a clear foundation, are lost. Mathematics is demoted from its status of absolute and timeless beauty and becomes a "quasi-empirical" endeavor. Formal axiomatic systems fail and meaning is lost in the mist of formal hyper-abstraction, only penetrable by a handful of minds. Bad news for the epistemic status of science.

Chapter 10: Ontological Enigmas: What is the True Nature of Reality?

The discovery of the Higgs boson closes a successful chapter of physics—and leaves us in the dark. The list of unsolved problems in physics is extensive and no empirical tether can guide the mind anymore. Moreover, the nature of reality is very puzzling. Why do three spatial dimensions exists? Why does our universe appear fine-tuned?

– Section 10.1: The Worst Prediction in Physics

Quantum filed theory is spectacularly accurate in describing the interactions of particles. However, it makes a fantastically absurd prediction when confronted with the zero-point energy of particles and the observable energy density of the vacuum.
The discovery of the accelerated expansion of the universe reopens an old chapter of cosmology. Einstein had tweaked the equations of general relativity to prevent an expanding universe. Ironically, this trick also can account for the energy density of the vacuum, driving the expansion of the universe.

– Section 10.2: Quantum Gravity: The Cutting-Edge of Theoretical Physics

The theory of quantum gravity, merging quantum mechanics with general relativity, is the holy grail of theoretical physics. Decades of work have resulted in an elaborate mathematical framework, called string/M-theory. Indeed, the development of this physical theory has resulted in the discovery of new fields of mathematics. Unfortunately, there is no empirical prediction anywhere in sight. Moreover, M-theory speaks of an eleven-dimensional space-time, containing supersymmetric particles. It was long hailed as the "only game in town." While string theory starts with quantum field theory and adds gravity, loop quantum gravity—the underdog of quantum gravity—takes general relativity and adds quantum properties. In this framework, space itself is quantized. The theory also allows older attempts at quantum gravity to reemerge. Overall, quantum gravity has been a hot battleground for physicists.

– Section 10.3: The Large and the Small

Analyzing the nature of reality at the largest and smallest scales reveals many enigmas. For one, both the positioning of the Earth in the entire universe, and the current time we are living in, appear special. Then, 95.14% of all that exists is unknown to us. We are surrounded by ghostly dark matter and energy.
At the quantum level of the universe, reality seems outlandish. The interpretation of quantum mechanics is—after over a century—as elusive and controversial as ever. Waves behave like particles and vice versa. Quantum sates are strange superpositions of clearly defined states: The 0/1 dichotomy of binary logic is transcended, as there exists a superposition of zero and one. Measuring quantum phenomena seemingly influences their properties. Reality is reduced to clouds of probability. Perhaps the strangest of all quantum qualities is entanglement. This acts like a structural glue connecting particles independently of their spatial distance—instantaneously. It is a feature at the core of quantum encryption. The story of its discovery opens a colorful chapter in the history of physics, involving hippies, psychedelics, and superstition. Countless quantum experiments verify that local realism cannot be true. Indeed, the "now" appears to alter the past. Explanations have invoked the existence of infinitely many parallel universes or the quantized nature of space itself. Other thinkers believe we should move to a wholly new informational foundation of reality, in order to make sense of our world. The materialistic and reductionistic scientific worldview is fading.

– Section 10.4: The Nature of Reality

The ontology of reality seems unknowable to the human mind. The true nature of things appears to transcend any and all human conceptions. Many physicists and philosophers answer the question "Does matter exist?" with a clear "No!" Perhaps even more troubling, they answer the question "Is time an illusion?" with a definitive "Yes!" Some see the problems related to consciousness itself.

Chapter 11: *Subjective Consciousness: What am I?*

What is consciousness? Remarkably, this innocuous question is one of the hardest the human mind has ever asked itself. It represents the last enigma in the journey of the mind to understand the universe and itself within it.

– Section 11.1: The History and Philosophy of Our Minds

In 1994, the hard problem of consciousness was stated. The "easy problem" of consciousness relates to explaining the brain's dynamics in terms of the functional or computational organization of the brain. The hard problem of consciousness is the challenge of explaining how and why we have phenomenal experiences? Why do we perceive colors, tastes, and pain? Why are we not "zombies?" How do the laws of nature give rise to first-person conscious experience?

– Section 11.2: Modern Neuroscience

Neuroscience has progressed remarkably in the last decades. Brain imaging technology allows researchers to track thoughts in the brain and read them. The brain is understood as a vast decentralized network of processes and modules interacting with each other. However, neuroscience also tells us that our perception of reality is a hallucination. Our brains construct a virtual reality simulation of the outer world based on best guesses. We can never know what the true nature of reality is. This view is similar to Kant's noumenon. As a result, we are blind to much of the activity going on in the world. Indeed, expectations and context can alter the way we perceive the world—from pleasure to pain. Flase awakenings and out-of-body experiences can shatter many intuitions about reality.

– Section 11.3: Impressionable Consciousness

Perhaps the most humiliating discovery relating to the human mind is its innate irrationality. We constantly fall prey to faulty reasoning and self-deceit, while proudly claiming rationality. The list of cognitive biases is frighteningly long. Our minds can be influenced by microorganisms, parasites, and genes. Or it can be purposefully manipulated. Even false memories can be implanted. By magnetic stimulation of the brain supernatural belief can be momentarily suspended while empathy for immigrants increased. Indeed, political affiliation is correlated with fear mechanisms. Behavioral economists have uncovered a trove of embarrassing findings exposing innate and ubiquitous human irrationality. Sometimes, even animals can outperform humans. It turns out that pigeons have a better intuition of probability than physics Nobel laureates.

Finally, the mind can break. This is documented by the many psychopathological disorders, from compulsive swearing to the firm belief that one doesn't exists. Split-brain patients can experience alien hand syndrome, where one hand becomes an adversary. Acquired savants display genius traits after brain trauma. Some case studies document normally functioning humans lacking vast parts of their brains. Neurolaw questions the culpability of certain criminals. Are we really free to choose if we have a brain tumor affecting vital emotional processing areas of the brain?

– Section 11.4: The Mind-Body Problem

The placebo and nocebo effects hint at an intriguing connection between the mind and the body. The mind can will the body into healing or harming itself. Then, free will is a thorny issue in physics as well as neuroscience. This may sound astounding, then how can free will be contestable? I choose to be reading this sentence in this moment. If there is no free will, then who or what is deciding and why? Quantum mechanics first discovered the problem of an observer in physics. Apparently, consciousness is able to manipulate physical reality. The status of free will in quantum mechanics is still far from being understood. It appears that we have to choose. Either there is no free will or everything in the universe is imbued with it. In neuroscience the situation is clearer. Many experiments have demonstrated how a decision is made in the subconscious mind which is then, seconds later, relayed to the conscious narrator. Of course, the conscious mind insists that it was the cause of the decision. Overall, consciousness seems to be an ironic anomaly which cannot be integrated into the scientific worldview it created itself.

Chapter 12: The Age of Post-Truth

The situation is dire. We have lost the guidance from science and philosophy and ignorance is rampant. Trench wars are fought along social, political, and religious delimitations. Hostility and misanthropy permeate the very fabric of society. We are lost in an existential vacuum, where we ultimately use the gift of technology to destroy the biosphere which provides the bases of all life.

– Section 12.1: The Cult of Ignorance

  Today, anti-intellectualism is socially acceptable. "My ignorance is just as good as your knowledge." Experts and scientists are perceived as villains who are deceiving the people—either for self-enrichment or by adhering to a sinister hidden agenda.

– Section 12.2: The Age of Conspiracy

  Conspiracy theories are surprisingly popular. From creationism, motivated by religious beliefs, to denying climate change, motivated by political beliefs, to the astonishing claim that the Earth is flat. Some conspiracies have been peddled for self-enrichment, like the false claims that vaccines cause autism. The most popular and widespread conspiracy is creationism, disseminated by Evangelical Christians mostly in the United States.

– Section 12.3: What About This Book?

  A superficial understanding of this book up to now could lead to the false belief that it can be instrumentalized for anti-intellectualism. The failure of science and philosophy to explain the world can be seen as an invitation for arbitrary beliefs about existence. Indeed, nothing is as it seems. Once this truth is admitted, the human mind can reconsolidate and search for new horizons. We are invited to reassess all our assumptions and be open-minded towards even seemingly "crazy" ideas. We should not be blinded by the illusion of knowledge. In being skeptical and honest, false ideas about existence can be eradicated, regardless of their origin. A new foundation is now possible.

– Section 12.4: The Dawning of a New Age

  Perhaps things are not as bad as they seem. We are seeing signs of an emerging new age. Perhaps we will soon be able to translate our amazing powers of individual intelligence into collective intelligent behavior. Maybe soon we can construct an economy that is adaptive, resilient, and sustainable. After all, the universe has an intrinsic propensity to forge complexity. Self-organization appears like a fundamental force guiding cosmic evolution.

  Pragmatically, we can assess human thought systems and check their level of scientific utilitarianism. Conspiracy theories, for instance, require many arbitrary and ad hoc explanations to account for simple facts. Most importantly, radical and empathetic open-mindedness can help us reevaluate all our beliefs. There is no idea which should be excluded based on our current materialistic and reductionistic scientific worldview. "The universe is queerer than we can suppose" and perhaps also our own minds.

Chapter 13: A Universe Built of Information

Paradigm shifts are hard to discern from within. However, slowly the evidence is mounting that humanity is currently witnessing a profound recontextualization of its belief systems. Specifically, the materialistic and reductionistic scientific worldview appears to have reached its limit—not only in terms of knowledge generation but also in its capacity to probe the ultimate nature of reality.

– Section 13.1: The Many Faces of Information

Information is hard to grasp. It appears ethereal and intangible, somehow detached from the physical. Its definition is a challenge in the philosophy of information. However, information is remarkably physical. Claude Shannon's information theory introduces the notion of quantized information: the bit. This unit is the building block for our modern digital computational world, established by Alan Turing. It was discovered that irreversible computational steps, for instance, erasing information, increases the entropy of the universe. Information cannot be destroyed—it is physical.

– Section 13.2: It from Bit

In a more radical assertion, two pioneers of modern theoretical physics believed that information is fundamental. "It from bit" popularizes the view that from an information-theoretic bedrock our reality emerges. Such views are shared by contemporary scholars of quantum information and computing. Indeed, the bizarre nature of quantum mechanics can be overcome by framing it in an informational context. At the core is the qubit, a quantum representation of a classical bit utilizing the multilayered nature of the quantum realm. Humanity is, however, only at the threshold of unleashing the powers of quantum computers. Historically, Charles Babbage and Ada Lovelace were the first to implement a mechanical computer.

– Section 13.3: Digital Physics

A group of contemporary scientists is advocating the idea of digital physics as an overarching concept. One postulate is that reality is inherently finite. Infinities are only encountered in the formal mathematical systems the human mind accesses.

– Section 13.4: An Information Ontology

Albeit tantalizing, up to now the human mind only caught a glimpse of this novel information ontology. However, there should exist more evidence to substantiate the claim. Indeed, by studying black holes many different theories converge and point in the same information-theoretic direction. General relativity uncovered the existence of black holes. Applying information theory and thermodynamics in their study resulted in more understanding. However, including quantum mechanics unearthed a paradox. In detail, it appeared as if information is lost in black holes violating the principles of quantum physics. Further research uncovered that there is a fundamental limit to how much information—how many bits—can be stored in any region of space.

Perhaps the most powerful tool coming from string/M-theory is the so-called AdS/CFT duality. In the context of black holes, it can be re-expressed as the holographic principle. Our three-dimensional world is in fact the manifestation of information encoded on a two-dimensional area. Moreover, space and time appear to be emergent properties arising from pure quantum entanglement. Finally, theoretical computer science is currently aiding the understanding of this new line of research. Specifically, computational complexity seems to be a likely candidate fueling the computational engine of the universe. In a last step, some scholars have expressed their suspicion that the entire universe is a simulation.

Chapter 14: *The Consciousness of Reality*

The connection between subjective consciousness and objective reality has been debated for ages. René Descartes and John Locke introduced primary and secondary qualities for objects appearing in the mind. Bishop Berkeley argued that all qualities reside in the mind. David Hume and Immanuel Kant rejected the empirical nature of knowledge. More recently, Hilary Putnam pondered the idea of brains in a vat.

– Section 14.1: Formalizing Consciousness: Integrated Information Theory

Integrated information theory (IIT) is the first formal attempt at grappling with consciousness. Next to information's observational and extrinsic nature, described by Claude Shannon, IIT deals with its compositional and qualitative nature. An inner view of information is presented, giving rise to subjective experience.

– Section 14.2: The Cosmic Nature of Consciousness

The recalcitrant nature of consciousness , stubbornly refusing to yield to a materialistic and reductionistic scientific worldview, has led scholars to debate seemingly outlandish ideas. A consequence of IIT is that consciousness is a universal—perhaps also fundamental—property of reality. Such concepts are dangerously close to notions of spirituality. Subjectivity was a taboo not too long ago, as is spirituality now. The emergence of intelligence in animals and plants, next to primitive organisms and even innate matter and pure software, appears to challenge the human mind's dominance—and intelligence's tangibility. Indeed, collective intelligence is a decentralized emergent property untethered from any individual localized cognitive capability.

– Section 14.3: Enhanced Consciousness: The Psychedelic Renaissance

For a long time, the scientific and societal verdict was clear: psychedelic substances have no potential benefits and lead the mind astray. In the current psychedelic renaissance, the remarkable therapeutic potential of these substances has been uncovered. Intriguingly, the human brain synthesizes the strongest psychedelic substance known: DMT. Influenced by this chemical compound, human consciousness appears to be "teleported" into realms of existence transcending space, time, and matter. These universes, experienced as being just as real—or even more real—as the reality perceived by sober waking consciousness, are populated with other alien conscious entities. Especially in shamanic traditions, the "plant spirits" give insights into healing. It is tempting to disregard such experiences as hallucinations, but how to discern, with certainty, what is true and what is false about our perception is very challenging. Particularly, as sober waking consciousness is also a hallucination induced by the brain utilizing some sensory input—rendering a tiny subspace within a much richer "reality topology" available to the brain.

– Section 14.4: A Participatory Ontology

John Wheeler was one of the pioneers to introduce the notion of an information-theoretic ontology into physics. Thinking this idea to its radical conclusion, he introduced the concept of a participatory ontology. This insight had also not escaped Immanuel Kant and Richard Tarnas. In the long and colorful history of quantum physics, many scholars believed the encountered enigmas and paradoxes originated from a fundamental misconception: the separation of mind and matter.
In a final act of heresy, the prevailing materialistic and reductionistic scientific world-view is denounced. All the associated taboos and blind spots are exposed. In the peer-reviewed scientific literature one finds hints of paranormal and psychic—or psi—phenomena. Reproduced double-slit quantum experiments demonstrating the human mind's role as quantum observer and manipulator. Indeed, other outlandish psi phenomena have been reproduced by skeptics, however, only to be dismissed.

Chapter 15: Consilience

This is the last chapter in the human mind's quest for understanding. As it is itself a summary of the entire journey, the reader is invited to directly continue there. Final thoughts and outlooks are provided.

– Section 15.1: The Inner and Outer Aspects of Information
– Section 15.2: The Rhizome of Reality and the Entelechy of Existence
– Section 15.3: A New Horizon

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