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Rerum fores aperuisse, Anaximander Milesius traditur primus.

It is said that Anaximander of Miletus first opened the doors of nature.

—*Pliny, Natural History 2*

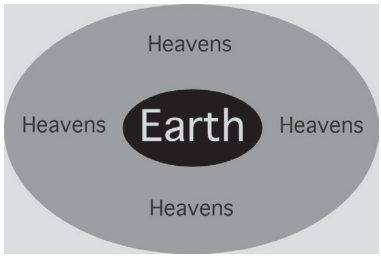

Figure 1a, left. Most early human civilizations viewed the world as the Heavens above and the Earth below. Figure 1b, right. The ancient Greeks saw the Earth as a stone floating in space.

Introduction

Human civilizations have always believed that the world consisted of the Heavens above and the Earth below (figure 1a). Beneath the Earth, to keep it from falling, there had to be more earth; or perhaps an immense turtle on the back of an elephant, as in some Asian myths; or gigantic columns like those supporting the Earth according to the Bible. This vision of the world was shared by the Egyptians, the Chinese, the Mayans, the peoples of ancient India and sub-Saharan Africa, the Hebrews, Native Americans, the ancient Babylonian empires, and all other cultures of which we have evidence.

All but one: the Greek world. Already in the classical era, the Greeks saw the Earth as a stone floating in space without falling (figure 1b). Beneath the Earth, there was neither more earth without limit, nor turtles, nor columns, but rather the same sky that we see over our heads. How did the Greeks manage to understand so early that the Earth is suspended in the void and that the Heavens continue under our feet? Who understood this, and how?

The man who made this enormous leap in understanding the world is the main character in this story:

'Αναξίμανδρος, Anaximander, who lived twenty-six centuries ago in Miletus, a Greek city on the coast of what is now Turkey. This discovery alone would make Anaximander one of the intellectual giants of the ages. But Anaximander's legacy is still greater. He paved the way for physics, geography, meteorology, and biology. Even more important than these contributions, he set in motion the process of rethinking our worldview—a search for knowledge based on the rejection of any obvious-seeming "certainty," which is one of the main roots of scientific thinking.

The nature of scientific thinking is the second subject of this book. Science, I believe, is a passionate search for always newer ways to conceive the world. Its strength lies not in the certainties it reaches but in a radical awareness of the vastness of our ignorance. This awareness allows us to keep questioning our own knowledge, and, thus, to continue learning. Therefore the scientific quest for knowledge is not nourished by certainty, it is nourished by a radical lack of certainty. Its way is fluid, capable of continuous evolution, and has immense strength and a subtle magic. It is able to overthrow the order of things and reconceive the world time and again.

This reading of scientific thinking as subversive, visionary, and evolutionary is quite different from the way science was understood by the positivist philosophers, but is also different from the fragmented, sometimes dry image of science provided by some more modern philosophical reflections on science. The aspect of science that I seek to illuminate in these pages is its critical and rebellious ability to reimagine the world again and again.

If this reimagining of the world is a central aspect of the scientific enterprise, then the beginning of this

adventure is not to be sought in Newton's laws of motion, in Galileo's experiments, or Francis Bacon's reflections. Nor even in the early and mathematical constructions of Alexandrian astronomy. It must be sought in what can be called the first great scientific revolution in human history—Anaximander's revolution.

There is no doubt that Anaximander's importance in the history of thought has been underrated.* I believe that this has happened for several reasons. On the one hand, in the ancient world, his contributions were recognized by authors of a scientific bent, including Pliny (as quoted in the epigraph to this book), but Anaximander was generally seen by the ancients, including Aristotle, as the proponent of a naturalistic approach to knowledge that was fiercely opposed by other cultural currents and that had not yielded much in the way of results. The naturalistic project, indeed, had yet to bear the rich fruits it would bear with modern science, after a long process of maturation and numerous methodological adjustments.

At the root of today's underestimation of Anaximander's thought, on the other hand, lies the pernicious modern separation between science and the humanities.

*The situation is changing. Several recent studies converge on this point. Daniel Graham, in *Explaining the Cosmos: The Ionian Tradition of Scientific Philosophy*, comes to conclusions very similar to the ones in this book. In the introduction to the essay collection *Anaximander in Context*, by Dirk Couprie, Robert Hahn, and Gerard Naddaf, we read, "We are convinced that Anaximander was one of the greatest minds that had ever lived, and we felt that this had not been sufficiently reflected in the scholarship, until now." Couprie, who has studied Anaximander's cosmology in depth, concludes, "I do not hesitate to put him on a par with Newton."

I am aware that my mainly scientific training makes evaluating the contributions of a thinker who lived some twenty-six hundred years ago a risky proposition, but I am convinced that most if not all of today's assessments of Anaximander's contribution suffer from the inverse problem—the difficulty that specialists in history or philosophy have in evaluating the importance of insights whose nature and legacy are intimately scientific. It seems to me that even the authors quoted in the last footnote, who recognize without hesitation the greatness of Anaximander's contributions, fail to grasp the full extent of the historical importance of his multiple insights for the development of science. I seek to highlight that importance in these pages.

Therefore I examine Anaximander not as a historian or as an expert in Greek philosophy, but as a scientist of today keen to reflect on the nature of scientific thinking and its role in the long-term development of civilization. In contrast to the majority of texts about Anaximander, my goal is not to reconstruct as faithfully as possible his thought and conceptual universe. For this reconstruction, I rely on the painstaking, magisterial work of classicists and historians such as Charles Kahn, Marcel Conche, and, more recently, Dirk Couprie. My goal is not to challenge the conclusions of their reconstructions; it is to shed light on the profundity of the thought that emerges from them, and the role of Anaximander's insights in the development of universal knowledge.

A more subtle reason for the underestimation of Anaximander's thought and of Greek scientific speculation in general lies in what I believe is a common misunder-

standing of certain central aspects of scientific thought.

Facile nineteenth-century certainties about science—in particular the glorification of science understood as definitive knowledge of the world—have collapsed. One of the forces responsible for their dismissal has been the twentieth-century revolution in physics, which led to the discovery that Newtonian physics, despite its immense effectiveness, is actually wrong, in a precise sense. Much of the subsequent philosophy of science can be read as an attempt to come to grips with this disillusionment. What is scientific knowledge if it can be wrong even when it is extremely effective?

A wide current in the philosophy of science has reacted by seeking to save a basis for certainty in science. Scientific theories, for example, have been interpreted as constructions whose value is limited to their directly verifiable consequences, within given domains of validity. The knowledge content of scientific theories has been interpreted as restricted to the ability to give predictions. In this way, in my opinion, we lose sight of the qualitative aspects of scientific knowledge and in particular of science's ability to subvert and widen our vision of the world. These qualitative aspects are not only inextricable from scientific thinking and essential for its functioning—they even constitute its primary motivation and reason of interest.

At the opposite end of the spectrum, another wide current of contemporary culture belittles scientific thinking and promotes widespread antiscience feelings. In the early twenty-first century, in many corners, rational science has come to be seen as suspect; forms of irrationalism have emerged in cultural circles and everyday life. Antiscientism feeds on the disillusionment over

science's inability to deliver definitive visions of the world—on the fear of accepting ignorance. False certainties are preferred to lack of certainty.

But answers given by natural science are not credible because they are definitive; they are credible because they are the best we have now, at a given moment in the history of knowledge. Lack of certainty is anything but weakness. Instead, it constitutes—and has always constituted—the very strength of rational thinking, understood as curiosity, rebellion, and change. It is precisely by not taking its answers as definitive that science can continue to improve them.

From this point of view, three centuries of Newtonian science do not constitute Science. On the contrary, they are little more than a moment of rest along the way, in the shadow of a great success. In challenging Newton's theories, Einstein did not question the possibility to better discover how the world works. On the contrary, he followed in the footsteps of Maxwell, Newton, Copernicus, Ptolemy, Hipparchus, and Anaximander, all of whom advanced knowledge by challenging the received vision of the world, continuously improving it—recognizing errors and learning to look further and further ahead.

The advances achieved by these great scientists (and by innumerable other minor ones) have repeatedly changed not just our worldview but even the very rules of thinking that structure that worldview. I believe that looking for a key to unravel all problems—a methodological and philosophical fixed point to which this intellectual adventure could be anchored—is to betray science's very nature, which is intrinsically evolutionary and critical.

For some time now, humanity has discovered a path skirting the certainties of those who claim to know ulti-

mate truths, while at the same time avoiding the downfall of claiming—as many claim today—that all truths are equal, each within its own cultural context, and we cannot distinguish true from false. This is the point of view that I shall seek to articulate in the final part of this text.

To look back at the ancient origin of scientific thinking, to the very first steps in the direction of rational inquiry about nature, is therefore here a way to shed light on some central aspects of the nature of this thought.

I think this reflection is important also for today's fundamental science. We are still immersed in the scientific revolution opened by Einstein.[1] To speak of Anaximander is also to grapple with the meaning of this revolution. My main scientific activity is in this field, and in particular in quantum gravity, a major open problem at the heart of today's theoretical physics. To address such a problem we likely need to change once again our understanding of the nature of time and space.[2] Anaximander succeeded in changing the old understanding of space, transforming the world from a closed box with the Heavens above and the Earth below to an open space in which Earth floats. I believe that only by understanding how such immense transformations of the world as Anaximander's are possible—and in what sense they are "correct"—can we hope to confront challenges like the changes in the notions of space and time demanded by the quantization of gravity.

Finally, there is a third thread running through this book: the discussion of a vast problem for which I can pose questions more than I can propose answers. As we examine the earliest ancient manifestations of rational

thinking about nature, we are naturally led to examine the mode of knowledge that historically preceded it—a mode of knowledge that today still affirms itself as an alternative to rational thinking. This is the mode of knowledge from which rational thought was born and differentiated itself, and against which it rebelled and still rebels.

When he "opened the doors of nature" (in Pliny's words), Anaximander ignited a conflict between two profoundly different ways of thinking. On the one hand, there was the dominant mythical and religious way of thinking, based in large measure on the existence of certainties that, by their very nature, could not be called into question. On the other hand, there was the new way of looking at the world, based on curiosity, rejection of certainties, and change. This conflict has run through the history of Western civilization, century after century, with alternating outcomes. It is still open.

After a period in which these opposing modes of thinking seemed to have coexisted peacefully, the clash appears to be reemerging today. Numerous voices, from political and cultural viewpoints that otherwise diverge greatly, once again speak out on behalf of irrationality and the primacy of religious thought. This renewal of the clash between positive and mythico-religious thought takes us back to the conflicts of the Enlightenment. But I think that it is a mistake to consider only the past decade or the past few centuries in attempting to clarify terms. The clash is more profound. It is measured in millennia rather than centuries, for reasons relating to the slow evolution of human civilization, the deep structure of its conceptual organization, and its gradual political and social evolution.

These are vast themes, and I can do little more than

ask questions and seek out some grounds for reflection in the final chapters of the book; but I believe that these themes are central to our world and its future. Every day, the uncertain outcomes of this conflict shape the lives and fate of all humanity.

I do not wish to overstate the importance of Anaximander. In the end, we know very little about him. But twenty-six centuries ago, on the Ionian coast, somebody opened a new path to knowledge and a new route for humanity. A thick fog veils the sixth century before the Common Era, and we know too little of the man Anaximander to be able to attribute this immense revolution to him with certainty. Still, this revolution, the birth of a thinking based on curiosity and change, took place. In the end, whether this change was wrought personally by Anaximander, or whether "Anaximander" is simply the name used in ancient sources to identify it, matters little.

This extraordinary revolution, begun twenty-six centuries ago on the coast of present-day Turkey, and in which we are still immersed, is the topic of this book.

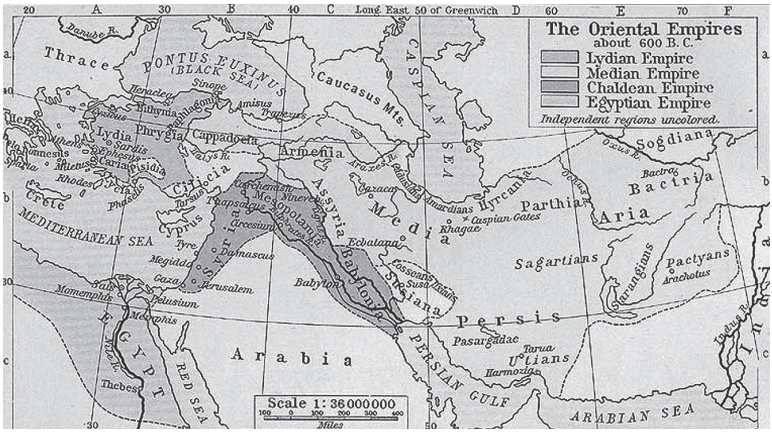

Figure 2. A nineteenth-century map showing the empires of the Middle East around 600 BCE.

ONE

THE SIXTH CENTURY

The sixth century before the Common Era (BCE) is not among the most widely familiar historical periods. When Anaximander was born in Miletus in 610 BCE, the Golden Age of Greek civilization, the time of Pericles and Plato, was still nearly two hundred years in the future. Tarquin the Elder, according to tradition, reigned in Rome. At around the same time, the Celts founded Milan, and Greek settlers from Anaximander's Ionia founded Marseille. Homer (or whoever for him) had composed the *Iliad* two centuries earlier, and Hesiod had already composed the *Works and Days*, but none of the other Greeks' illustrious poets, philosophers, and dramatists had begun writing. Sappho, still a girl, was living on an island near Miletus.

In Athens, whose power was just beginning to grow, Draco's strict code of law ruled, but Solon, who would write the first constitution to incorporate democratic elements, had already been born.

The Mediterranean world was far from primitive. Humans had been living in cities for at least ten thousand years. The great Kingdom of Egypt had been in existence for some twenty-six centuries—the same span of time that separates Anaximander from us.

Two years before Anaximander's birth, the city of Nineveh had fallen, a momentous event that marked the end of Assyria's vast and brutal power. Babylon, with more than two hundred thousand inhabitants, was once again the largest city in the world, as it had been for thousands of years. Nabopolassar ruled over Babylon, but the city's return to splendor would be short-lived. Under Cyrus I, Persia's power was already stirring in the east, and the Persian Empire would soon take control of Mesopotamia. In Egypt, it was the last year of the long reign of the great Psamtik I, the first pharaoh of the Twenty-sixth Dynasty, who had won Egypt's independence back from the dying Assyrian Empire and restored prosperity to his realm. Psamtik I had established close relations with the Greek world: he had enrolled numerous Greek mercenaries in his army and encouraged Greeks to settle in Egypt. Miletus maintained a flourishing port of call in Egypt, at Naucratis. Anaximander, then, likely had abundant first-hand information about Egyptian culture.

Josiah of the House of David reigned over Jerusalem. With the Assyrian Empire weakened and Babylonia not yet restored to full power, he took advantage of international instability to reaffirm Jerusalem's pride by imposing exclusive worship of the single God, Yahweh. He destroyed all the ritual objects of other gods (such as Baal and Astarte), tore down their temples, massacred their living priests, and exhumed and burned upon their altars the bones of the dead priests,[1] establishing a mode of

behavior toward other religions that would later characterize triumphant monotheism. Before Anaximander's death, the Israelites fell captive again and were deported to Babylon, where they once again knew servitude—a servitude from which they would once again win their freedom, as they had centuries before from Egypt, with Moses.

Echoes of these events surely reached Miletus. News of happenings elsewhere in the world probably did not. Northern Europe was passing from the Bronze Age into the Iron Age. In the Americas, the ancient Olmec civilization was already waning. In northwest India, the Mahajanapada kingdoms had formed. Mahavira, a contemporary of Anaximander in India, founded Jainism and preached nonviolence toward all living beings. Already the Indoeuropeans of the West were focusing on how to better think about the world, while those of the East reflected on how to better live.

In China, King Kuang of Zhou had recently ascended to the throne as the twelfth emperor of the illustrious Zhou Dynasty. It was the so-called Spring and Autumn Period, a time of decentralization of power and feudal battles—and of cultural diversity and creativity as well. China would not know a similar culturally productive era for a long time to come. This has perhaps been the price paid for an internal stability that, while imperfect, has nevertheless far exceeded that of the ferocious West, endlessly at war.

Human civilization, thus, had been in existence and highly structured for thousands of years when Anaximander was born at the dawn of the sixth century BCE. The traffic of goods and ideas among continents was intense. At Miletus, it was perhaps already possible to purchase Chinese silk, as would be the case two centuries