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The enchantment of the world:
An alternative history of the natural sciences

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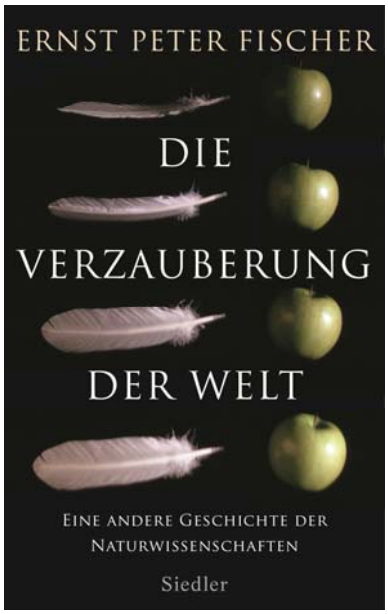

Preface: The Lost Sense of Wonder

You cannot say that physics has explained away the secrets of nature, only that it has related them back to even deeper secrets." - Carl Friedrich von Weizsäcker.

Albert Einstein once said that the most beautiful thing human beings can experience is mystery, which he defined as the "basic feeling at the cradle of all true science and art." People today are losing this feeling in a number of ways. Or, perhaps more accurately, it is being taken from them - for instance, when social philosophers announce that the natural sciences are "disenchanting" the world. Many journalistic purveyors of science also subscribe to this idea, writing bold headlines like "Secrets of the Waggle Dance Unraveled" in an attempt convince readers they have a deep knowledge of the lives and activities of bees. In fact, they have no such knowledge. The waggle dance phenomenon has never been fully explained. Talking heads of all varieties compete with one another to tell the public about all the marvelous things science has explained away. Cancer is caused by the multiplication of degenerate cells. People perceive color thanks to differing wavelengths. The surface tension of water is down to its molecular form. Atoms emit light. Energy is released via the processes of nuclear fission and fusion. Etcetera, etcetera.

Some time ago, literary critic Erich Heller complained that the brightly colored images television uses as scientific explanations of things like virus and their effects do less to help viewers understand the subject matter than to "immediately transport them into a Disneyland full of vivid absurdity." The garish flicker of hectic jump-cuts robs them of any appreciation of the mystery nature presents to those who observe and study it in detail.

We human beings are not primarily rational, but rather sensually perceptive and aesthetically sensitive creatures who automatically seek to discover beauty in the world. Among other things, we are delighted by the spectrum of things light can do. Light can sparkle, beam, illuminate, shine, warm, lighten, gleam and flash. It can be reflected, polarized, produced by extremely advanced diodes and released and employed in special forms by lasers. Light offers us a great many sensually perceptible secrets that inspire us to seek out similar phenomena. That is, it does insofar as education hasn't completely killed out curiosity. In school, the wonder of

such phenomena is too often obscured by the black lines textbooks use to illustrate the light paths resulting from telescopes, microscopes and prisms. There are even illustrations of the law of reflection governing what happens when lights hits a mirror that represent the mirror, too, as a black line. In the professional pedant's mind, one black line makes contact with another – this has absolutely nothing to do with what children actually see. All is clear. The black lines explain everything, converting it into a formula which can be known and tested in exams.

No one seems to notice that, in the process, children's natural delight in understanding their world is extinguished and the phenomenon of light is stripped of all its magic. The schoolteacher's black lines eradicate pupils' aesthetic curiosity about light's pleasing appearance. The cold, analytic rationality of scientific researchers, some might say, demands that something be sacrificed. In reality, however, such didactic illustrations have nothing at all to do with what fascinates physicists and other scientists when they start investigating light. Anyone who engages with their true perspective will realize just how far off the mark the grotesque idea of science demystifying the world truly is. This book, as an "alternative history of natural sciences," attempts to illustrate and expand on this idea using a number of concrete examples.

As we will see, scientific explanations of the world actually increase its mystery, making it more captivating and delightful. The scientific community is not , as American cultural theorist Francis George Steiner argued in his book *Grammars of Creation,* an anonymous, lethargic collective movement capable only of identifying "shallow truths." On the contrary, creativity is an essential element of most scientific progress. Science doesn't consist of mere discoveries in the sense of uncovering already present facts. Upon closer examination, it is a free product of the human imagination.

For decades, physicists like Carl Friedrich von Weizsäcker have distinguished between "deep" and "shallow" truths. The opposite of a shallow truth – electrons are electrically charged – is a falsehood. The opposite of a profound truth – electrons are particles – is another profound truth: electrons also behave like waves.

In his day, the philosopher and physicist Weizsäcker was confronted by the mysterious stability of atoms, which physics could only explain by hypothesizing quantum leaps between atoms' stationary condition and the forms atoms assumed.

As productive as this idea proved for the further development of physics, no one would claim that it explained away the original mystery. By contrast, anyone can see that the mystery of atoms, which remains an open question today, was further deepened.

Truths of Science

Proclaiming the truth in the way that religions do isn't part of the original aims of science. Nonetheless, there's no reason why we should shy away from enumerating ten truths we owe to the work of natural scientists. Science strives, on the one hand, to increase our enjoyment of perceiving the world and, on the other, to make our lives easier. Fortunately, in the search for knowledge to achieve these ends, insights universal enough to be called truths have emerged. Several of them are listed below. All will crop up again later in this book and will be left without explanation at this juncture.

1) Energy cannot be destroyed.
2) Atoms aren't things. They get their appearance from human beings who encounter themselves in the innermost workings of the world.
3) The universe is finite and without borders.
4) Reality is a whole without parts.
5) The world is full of possibilities. It is not just everything that is, but everything that could be.
6) Human beings are both spectators and actors in the theater of the world, inside which the drama of life plays itself out.
7) For every description of reality there is a second equally valid one, even if it contradicts the first one.
8) Life can only be understood in light of evolution and produces itself in a creative process.
9) Descriptions of what is real require an unreal (imaginary) dimension.
10) All human beings are responsible for the consequences of science since it is the source of their history. Those who do not understand science do not understand themselves.

Falling Down

The idea of science making mysteries more profound is more directly and easily understandable, if we take the example of free fall, which has puzzled people ever since the days of Aristotle and the Antique philosophers. Why things fall down is a question that gets posed over and over. Even if kindergarten children sometimes answer, much to the amusement of adults, that things fall down because all the things that fall up are long gone.

Aristotle thought he could solve the problem of why objects always fall toward the ground by positing an inherent destination. He assumed that all things had a rightful place in the world. In the case of falling objects, that place was on the ground. It took quite a long time before this explanation, which wasn't scientific in the modern sense of the word, was replaced by a better one. It was advanced in the late 17th century by Sir Isaac Newton who was looking less for a reason than a cause for the fact that apples fell to the earth when you shook the branches of an apple tree while the moon stayed in the heavens, calming orbiting the earth, instead of drifting off into space or crashing down upon the planet.

Newton developed a general theory of forces that caused motion. He called the one that caused apples to fall to the ground gravity. Ever since, the question of why things fall has been considered solved. Even schoolchildren learn that objects fall to the ground because of the earth's gravitational pull. The riddle has been solved, and you might think that the phenomenon of falling has been demystified. But you'd be mistaken. Through Newton, science offered something far better than demystification: an optimal example of what Weizsäcker characterizes as science's fundamental merit. Newton's theory related the mystery of falling back to the deeper mystery of gravity.

Is gravity truly a mystery? Anyone who thinks it isn't should try to explain clearly and concisely: 1) what causes gravity; 2) how the earth and its mass are able to exert this effect; and 3) how gravity can reach objects at high elevations like an airplane flying through the sky or the moon in its orbit. How can a propulsive force emerge from a body at rest? And how can it overcome distance in all dimensions and directions? I suspect that most people, including the majority of science experts in the media, would have to take a pass here or with the questions that arose from nearly

all the explanations they did hazard. There's always a next question. Wondering knows no end. That is the point of this book. It's not just natural phenomena that are full of mysteries. So, too, are the explanations presented and probed by natural science.

The Disenchantment of Disenchantment

Max Weber employed and popularized the oft-used and much-criticized phrase "disenchantment of the world" in his famous lecture "Science as a Vocation," which was published in book form in 1919 and remains in print in diverse editions today. In it, Weber speaks of an "inner calling to science" and emphasizes that "nothing is valuable to man, if he cannot do it with passion." This is precisely the way of scientists past and present, including Weber's contemporaries Einstein and Max Planck, whom humanity has to thank for the mysterious idea of quantum leaps. The duo of Planck and Einstein explained to at least one expert in the humanities, theologian Adolf von Harnack (1851-1930), why there were no philosophers worthy of note any more in turn-of-the-century Germany. Philosophers still existed, wrote Harnack, but they were now all working in physics departments.

Weber held his lecture at a time when the precursor to today's Max Planck Society was professionalizing science. Nonetheless, Weber held that increasing rationalization on the basis of science and scientific technology had not been accompanied by a "greater knowledge of the conditions of life." To illustrate what he meant he compared his audience to American Indians and Hottentots, whom he described – in keeping with attitudes at the time – as "savages."

Weber pointed out that "savages" knew far more about their tools than the students he was talking to did about the technology behind the street cars that conveyed them to his lecture. That lack of knowledge, Weber claimed, was not a problem for members of civilized societies because they trusted that they could acquire it, if necessary, with the help of experts. Weber's exact words were:

> The increasing intellectualization and rationalization do not, therefore, indicate an increased and general knowledge of the conditions under which one lives. It means something else, namely, the knowledge of belief that if one but

> wished one could learn it at any time. Hence, it means that principally there are no mysterious incalculable forces that come into play, but rather that one can, in principle, master all things by calculation. This means that the world is disenchanted. One need no longer have recourse to magical means in order to master or implore the spirits, as did the savage, for whom such mysterious powers existed. Technical means and calculations perform the service. This above all is what intellectualization means.

Weber didn't coin the phrase "disenchantment of the world." It was already in currency in theological circles, where it was used in the context of the "secularization of the cosmos." Max Horkheimer and Theodor Adorno would later revive in *The Dialectic of Enlightenment*, where they claimed that "disenchantment" was part of the "program" of the Enlightenment. In their view, "calculability" had developed into a "system of explaining the world." Following the drive to subjugate all aspects of nature, "instrumental rationality" subjected all thinking subjects to the constraints of economy and technology, transforming them into objects.

But let's return to Weber's lecture. The first thing to note is his choice of the streetcar as an example of the "rationalization" of the world at a time when science was investigating X-rays and radioactivity, hormones and vitamins chemotherapy and the first models of atoms. Did all of these things not pique his curiosity?

Weber apparently believed that in physics the terms mysterious and incalculable meant one and the same thing. Whatever physicists could calculate was no longer mysterious, and the mysteries of nature remained immune to scientific calculation. But this is far from the case, as the example of falling shows. It is possible to calculate very exactly the rate at which a given body will fall without having the slightest inkling of gravity. As precisely as Danish physicist Niels Bohr could calculate the orbits of electrons in atoms, the reason for the stability of the whole remained a complete mystery. A new sort of physics was needed. The question was: what sort?

The example of the streetcar was poorly chosen in another sense as well. Was it indeed the case that Weber's students were able to learn "at any time" why an electric street moved and how to apply the brakes? That presumed that there was an expert in the halls of science or a book in the library to explain what precisely was

happening in the natural and technological world when electricity was converted into motorized energy.

In this case, the expert would have been someone like the inventor of the AC induction motor, Croatian Nikolas Tesla (1856-1943). Looking back on his youth, he wrote: “Every day I asked myself what electricity was without finding an answer. Eighty years have gone by, and I’m still asking the same question without discovering an answer.” If today’s physicists still have trouble comprehending gravity and don’t know what it is, and if someone like Tesla, while knowing that neither we nor the world would exist without electricity, still didn’t know what electricity is, then no one knows these things. In other words, the world has not been disenchanted at all. On the contrary, the scientific approach to the world we know has significantly contributed to making it even more mysterious. Science shows how many secrets reality contains.

Mystery as a Concept

Before we proceed to look at how scientific examination deepens the mysteries of nature, let’s scrutinize the concept of mystery itself. The idea can be found in all sorts of late-nineteenth-century reference works, even though this was an age when many people believed that the work of physics would soon be done. Max Planck himself used to tell the story of how back when he was twenty years old a respected professor tried to dissuade him from studying physics. The book on physics had already been written, he was informed. All that was left was to dot a few i’s and cross some t’s.

The German word for mystery is *Geheimnis*. In a reference work from 1889, it is defined as such: “Everything obscure, concealed and incomprehensible, particularly in a religious context. In this sense, the teachings of the Holy Trinity and the dual nature of Christ, for example, are referred to as mysteries.” (A lot of other things were as well, which doesn’t seem very enlightening to people who live and think in the 21st century.) One hundred years later, in 1989, the leading German encyclopedia still discussed mysteries primarily in reference to theology, although the definition was hardly more comprehensible or adequate: “Generally speaking, what has not (yet) been recognized, as well as that which fundamentally doesn’t admit of

rational comprehension or which seems not to admit of rational comprehension according to the current state of science, or that which – in the religious sense – is deemed to be beyond rational comprehension. In theology, mystery refers to a truth that can only be known through the word of God and that can be partially comprehended after such a revelation while partly remaining in the dark."

Mystery as underlying truth. Twentieth-century natural scientists have also contributed a lot to this idea. In the scientific context we are focusing on here, it's useful to distinguish between what's mysterious and what's puzzling. A puzzle has a definitive, ultimate solution, whereas mysteries imply an open and open-ended story. The fact that there is a correct solution is part of the fun of crossword puzzles, and when someone writes a doctoral thesis in biology, he or she wants to complete it at some point. In this sense, you could say that the point of research is to solve a puzzle in the realm of science and scientific thought. This might be, for example, the question of what signals cells use to communicate with one another within a single organism, and the solution might consist of identifying and naming certain chemical substances or electrical currents. This would be an important first step – and enough for a successful doctoral thesis. It would not, however, end the line of enquiry. The riddle surrounding the molecules concerned would have been solved, but the mystery of animate reciprocity that allows cells to behave in this way would remain as intriguing as ever. This is the appeal of scientific research. It begins practically, by trying to solve a puzzle. But in so doing it also come closer and closer to the deeper mysteries of nature.

As nice as it is to solve riddles, it's equally nice that mysteries remain. You could say that humankind exists in a cosmos full of mysteries, and that this will never change. While the natural sciences first learned to see the universe this way in the 17th century, and the modern form of this basic idea is very recent, religiously-minded people believed from very early on that they lived in "an age of mysteries," to use historian Daniel Jütte's term for the centuries between 1400 and 1800. Jütte even wrote of an "economy of mysteries" in which Christians and Jews participated. In the centuries surrounding the Renaissance individuals traded in practical mysteries such as the production of powders or weapons. In today's language, we would speak of medicinal or technical know-how, which always comes at a price. In sixteenth-century Italy, there was a whole caste called the *professori de'secreti*.

On the one hand, people understood mysteries as *arcana naturae* or *arcana mundi*, secrets of nature or of the world. Today we speak of the secret, the occult and the mysterious. Secret in the sense of “top secret” requires no explanation. The occult refers to things that have been purposely left obscure and are only accessible to those in the know. The mysterious encompasses those things that are fundamentally unknowable to human minds.

Let’s let the Enlightenment philosopher Immanuel Kant (1724-1804) have the final word on this subject. In his treatise “Religion within the Boundaries of Mere Reason,” Kant writes of the mystery that can be found in every religion and that refers to the sacred. He describes it as “that which is known by every individual but not known publicly and which cannot be generally communicated.” Kant calls the sacred secret of religion its mystery and distinguishes it from the “arcania” of nature and the “secreta” of politics, both of which can be known if they are based upon causes that stem from experience and admit of scientific investigation.

In conclusion, it’s worth returning to the beginning of this chapter and trying to summon up Einstein’s appreciation of mystery. Part of the great physicist’s personal experience was that human being’s attraction to what was pleasantly mysterious led to their creation of what they call science and art. In other words, those who retain their trusty child-like sense for the mystery inherent in all things and who don’t let themselves be robbed of this enthusiasm by the pedantic forces of society will find pleasure in scientific thought and artistic creativity as adults. These two productive forms of human activity sometimes coincide, as we shall see in this book, and when they do the result is the essence of humanity to which we all aspire. Human beings search for mystery and find themselves in its bounty. Or to speak with the Romantics: “Where are we going to? Always back home.”