2 Reduction and Emergence

Introduction

The first step in understanding consciousness is to examine how we understand other things in the world. Reduction and emergence are the two main principles that we use to learn about the reality around us. Reduction is a top-down approach, breaking our complicated existence into more basic elements. Emergence is much the opposite, seeking to comprehend how complex entities arise from the interaction of fundamental components.

The Method of Reduction

The human mind inherently tries to understand complex things by breaking them into simpler components. This is a basic strategy we have all used since childhood; it is a fundamental part of the way we think. Analyzing problems in this way is called **reduction**, since it reduces something that is complex into something that is more elementary. It is the single most important method used by both scientists and everyday people to understand the world around them.

Let's look closer at how reduction works and the kind of knowledge that it leads to. As an example, suppose that we encounter a grandfather clock for the first time and want to understand it in the greatest possible detail. Figure 2-1 illustrates the method we will use. We start by dismantling the clock piece-by-piece, taking great care to record how the individual components fit together. This disassembly leaves us with a few hundred parts spread out on our work table, plus a

notebook full of sketches and descriptions that indicate how the parts can be assembled into the original object.

At this point we ask the question: "What is a grandfather clock?" Our answer is simply: "A grandfather clock is the several hundred parts resting on the table in front of us, assembled in the way indicated by the notes we have taken." In other words, we have reduced the original object to two things: (1) a set of smaller objects, and (2) the assembly instructions.

Being good scientists, we want to continue this analysis to its fullest conclusion. This means we need to consider each of the individual parts one-by-one, trying to reduce each to even more basic components. For instance, we might find that the face of the clock is a steel plate with a white background and black numbers. Accordingly, we stop thinking of the clock face as a single thing. Rather, we begin to view it as a sheet of metal and two kinds of paint, assembled in a specific way that we write down in our notebook.

As we continue this process we eventually encounter objects that are composed of a single material, for instance, the glass window that the clock face is viewed through. We can no longer reduce this type of object by simple mechanical disassembly; the chemistry of the materials must be examined. For this particular example, a chemist may tell us that the glass is composed of atoms of silicon and oxygen, combined in a certain molecular and physical way. To fully reduce the object we must specify the type and exact location of each and every atom that forms the object. In addition, we also need to specify the state of each of these atoms, such as how they are bonded to neighboring atoms to form molecules, as well as similar properties that chemists and physicists know about.

While this level of reduction is possible in principle, it is far beyond our present technology to actually carry it out. First, atoms are extremely small, making them very difficult to observe and measure. Second, the sheer number of atoms is enormous, far too large even for the most powerful computers

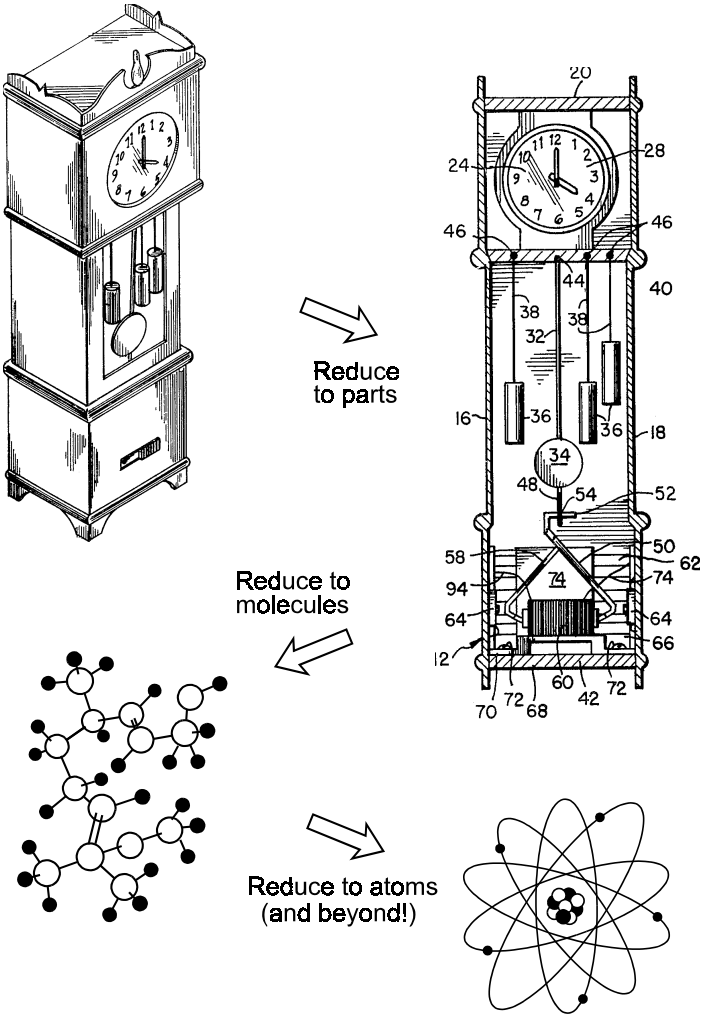

FIGURE 2-1
Objects to atoms. The method of reduction breaks objects into elementary components through a systematic series of steps. In this example, a grandfather clock is reduced to its component parts; each of the parts is reduced to its component molecules; and each of the molecules is reduced to its component atoms.

of today. For instance, there are about a million million million atoms in a single spec of dust. Will this level of reduction ever be feasible? Maybe, but certainly not in the next few decades; maybe not even in the next few centuries. However, the general idea is not as far fetched as you might think. As shown in Fig. 2-2, the detection and manipulation of individual atoms is something that can be done today.

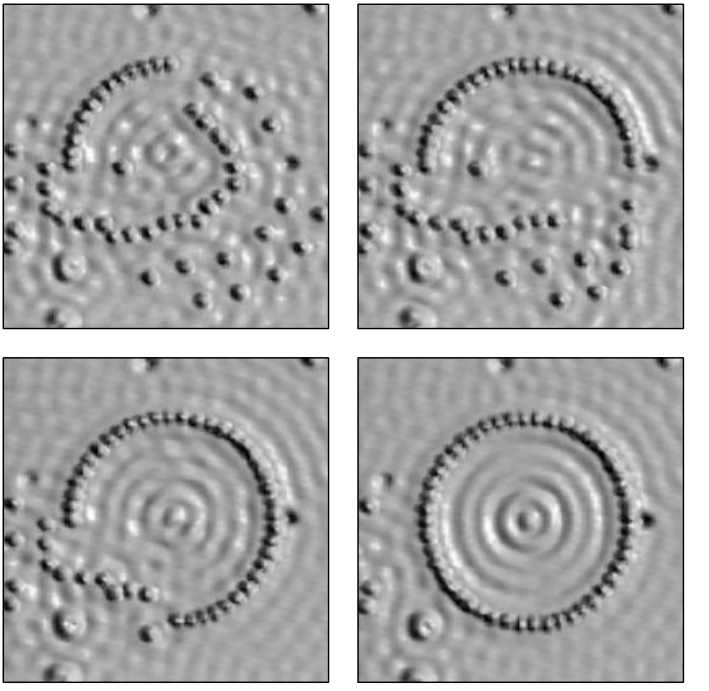

FIGURE 2-2
Manipulation of individual atoms. In the early 1990s, scientists at IBM demonstrated that the *scanning tunneling microscope* could be used to move atoms into various formations, in addition to creating images of them. This sequence shows individual iron atoms, resting on a sheet of copper, being moved into a circle 5000 times smaller than a human hair. ["Confinement of electrons to quantum corrals on a metal surface," M.F. Crommie et al., Science 262, pp218-220, 1993].

The important concept is that the principle of reduction allows us to understanding the world by breaking it into smaller and smaller components. But where does this end? At what point can reduction no longer be carried out? A simple answer can be given to these questions. The method of reduction ends when the things being considered can no longer be broken apart; that is, when we have reached things that are **irreducible**.

Identifying these irreducible things is one of the primary goals of science. If you open an introductory textbook on physics you will find many irreducible things discussed. This includes particles such as electrons, protons, and neutrons, the components that form atoms. It also includes forces, such as magnetism and gravity. Even stranger, we must include the dimensions that we exist in, namely, *distance* and *time*.

Since these things cannot be analyzed by reduction, there is an inherent barrier to knowing exactly what they are. We can easily measure their characteristics and how they relate to each other, but why they have these characteristics and behaviors is much more mysterious. For instance, it is well known in science that an electron moving through a magnetic field will travel in a curved path. The amount of curvature can be calculated from the details of the problem, such as the speed of the electron and the strength of the magnetic field. However, this tells us nothing of what an electron is, or what a magnetic field is, or why the interaction takes place. In short, we can accumulate knowledge about how these irreducible things behave, but not about what they are.

Day-after-day we exist in something we call **reality**. It is what we perceive with our five senses: vision, hearing, touch, taste, and smell. It is what we measure with our instruments, such as thermometers, rulers and clocks. Reality is as familiar as anything can be. But what is it? The method of reduction is an attempt to answer this question by separating reality into two categories: (1) those things that are irreducible, which we will call the **Elements-of-reality**, and (2) the assembly instructions,

which are **Information**. Figure 2-3 illustrates this extremely important concept.

These two categories have very different characteristics. The Elements-of-reality are tangible; they can be measured with our instruments; they seem to have a real existence independent of our paying attention to them. And of course, they are irreducible, by definition. On the other hand, the assembly instructions are a type of Information. Information exists only when stored in some kind of physical medium, such as writing in a notebook, electronic signals in a computer, chemical changes in a brain, or the energy fluctuations in a radio wave. It can also be transferred from one storage medium to another without changing its content in the slightest. However, Information is lost forever when its storage is interrupted for even the shortest instant of time. One way to capture these elusive characteristics is to define Information as the thing that can be passed over a communications channel. Let's look at an example to see how this works.

The Transmitted Hourglass

Suppose in the future we make contact with an extra-terrestrial civilization by radio signal. We find that the aliens are rather like us, having bodies that operate on similar chemistry and biology, and minds that think much the way we do. This is fortunate, because it allows us to create a common language for exchanging ideas. We go about this in much the same way that a child learns to speak. At first we transmit pictures of common objects, along with the nouns we use to describe them. Next, we transmit pictures of actions, along with the associated verbs. This leads to the generation of sentences, a dictionary, and the ability to express abstract concepts. Our communication with the aliens may not be perfect, but language never is, even between humans. The point is, there is no reason to think that our different backgrounds would stop us from communicating altogether.

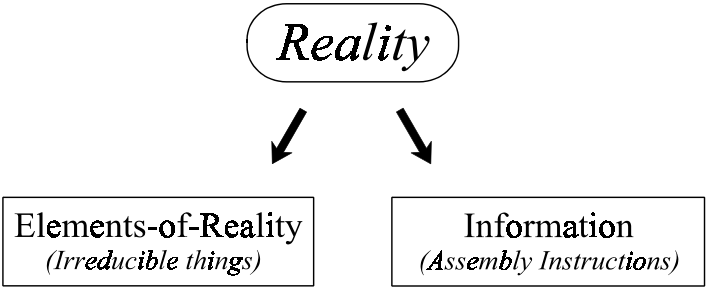

FIGURE 2-3
The endpoint of reduction. The method of reduction systematically breaks reality into two categories, the Elements-of-reality, which are irreducible, and Information, consisting of the assembly instructions.

Since the aliens exist in the same universe as we do, they will have the same Elements-of-reality, thereby providing common ground to build upon.

After a few initial exchanges, the aliens send a message indicating they want to build one of our historical artifacts, so that they can better appreciate our technology and culture. The device they select is an hourglass, and they ask us how they should go about the fabrication. Our response is the most complete description possible, starting with how the individual electrons, protons, and neutrons are combined to form the required atoms. Next, we describe the position of each and every atom that is needed to form the hourglass, and how they are interconnected with each other. The size of the transmitted description is enormous, and we can't imagine that it is lacking in any way. We also provide instructions for calibrating the device, since we know that the alien planet will probably not have the same gravitational field as the earth. This tells the aliens how to change the distance across the neck of the hourglass so that the sand will drain in the correct amount of time.

Some time later we receive a reply from the aliens thanking us for our help. They inform us that they were able to build an hourglass using electrons, protons, and neutrons from their home world, assembled according to the instructions we provided. They also tell us that the calibration procedure worked just as we indicated it would. The aliens' success is no surprise to us since they had access to everything they needed: Elements-of-reality, which they had locally, plus the assembly instructions we transmitted over the communications channel. Is there anything that the aliens could not reconstruct by using this procedure? According to the method of reduction, no. Taken to an extreme, the aliens could even create a duplicate of the entire earth with all its inhabitants. All they would need is enough raw materials and the assembly instructions.

Now suppose that a few years later we are contacted by another extraterrestrial being, one that is unlike anything we know. This alien does not even reside within our universe, but in another dimension. The radio signal has somehow managed to cross the boundary between the two realms. For the sake of argument, we will assume that we can establish a common language for communicating with this being. Based on our previous success, we send the Information about the hourglass to the strange creature, and suggest that he build one to better understand our species and civilization. Much to our surprise, the alien replies: "Thanks for the Information and I will try, but there are a few things that I will need. Please send electrons, protons, neutrons, distance, time, and gravitational field." To our astonishment, we realize that we are communicating with a being that does not have the same Elements-of-reality that we do. The alien has the instructions for constructing the hourglass, but none of the raw materials.

Fuzziness of the Endpoint

While the method of reduction is a powerful tool for understanding the world around us, it does have limitations. A primary problem is that our knowledge of the Elements-of-

reality is quite fuzzy and not well defined. This is because science keeps getting better at breaking things into more basic components. For instance, in the 5th century BC the Greek philosopher Empedocles believed that everything could be reduced to just four basic elements, air, fire, earth, and water. Scientists in the 1800s began to suspect that atoms were the basic element of all matter, a belief that Albert Einstein turned into accepted science in 1905. But this was short lived; by the 1930s it was known that atoms are formed from three more basic particles: electrons, protons and neutrons. By the 1960s these were further reduced into components called *quarks*. Today, research is attempting to express the world as even more fundamental entities known as *strings*.

The point is, science has not yet discovered the ultimate Elements-of-reality. The "best guess" has changed many times in the past, and will undoubtedly change many times in the future. Science inherently progresses by incremental steps. We are in the middle of this process, not at the end.

However, we are fortunate in one important respect; we live at a time when the search for the Elements-of-reality no longer involves the things in our day-to-day lives. As little as a few hundred years ago we could not answer the most basic questions of our everyday existence: Why does the sun feel warm? Where does water go when it evaporates? How does a poison kill us? Today we understand these things in great detail through the method of reduction. While the reduction process has not yet produced its final answers, the fuzzy edges have been pushed to very extreme realms, such as the nature of quarks, and how the big bang created the universe. These frontiers of knowledge are now so specialized and complex that they cannot be understood by the everyday person, or even the everyday scientist. Only scientists that have spent years studying these problems can grasp what they are really about. In the twentieth century the method of reduction moved from the realm of everyday experience to the realm of pure science

and mathematics. This is clearly one of the most momentous landmarks in all of human development.

This also sets a milestone in the study of consciousness, since it defines where the human brain fits into the scheme of things. Research during the last century has clearly shown that the brain operates by biology and chemistry, both of which arise from the interactions of atoms. Things smaller than atoms, such as quarks and strings, do not directly affect the operation of the brain, any more than they affect the operation of grandfather clocks and hourglasses. In other words, the fuzziness of the endpoint of reduction is almost certainly no longer relevant to our understanding of brain activity.

Consistent and Chaotic Realities

Why does the method of reduction work in the first place? To answer this question, imagine living in a reality of chaos, one that is ever changing and unpredictable. For instance, we might try to analyze our grandfather clock by the method of reduction on five successive days, Monday through Friday. On Monday we find it is composed of atoms in some particular arrangement. On Tuesday we find it is irreducible, and must be taken as an Element-of-reality in itself. The analysis on Wednesday reduces it to only two Elements-of-reality, simply placed side by side. Thursday's reduction shows the same two Elements-of-reality, but this time one inside the other. On Friday, we find it is rapidly oscillating between being composed of atoms and being a single irreducible object. Can we make sense of this changing reality? Does the method of reduction have any meaning or use under these circumstances? How do we go about understanding what we observe?

Fortunately, science does not have to answer any of these questions, because we live in a universe that is well behaved and consistent. As far as we can tell, what was found yesterday is what will be found today and again tomorrow. The physical laws that apply on the earth also apply across the galaxy and across the universe. That is, our ability to make observations

and use reduction does not change with time or distance. Science, as we know it, is critically dependent on this kind of consistency. Even Quantum Mechanics and General Relativity, strange as they may be, are very consistent.

Why does the method of reduction work? The answer is simply because *it does*. It is an observed fact, a characteristic of reality as we know it. However, as we will discuss in later chapters, this does not preclude the possibility of private realities (such as dreams) that are poorly behaved and full of chaos.

Emergence

The term *Gestalt* is used in psychology and elsewhere to mean, "the whole is more than the sum of the parts." For instance, the Gestalt view of a grandfather clock is that it has characteristics of its own, over and above the metal, wood and glass components that it is made from. After all, a grandfather clock tells the time, controls the storage and release of energy, inspires a sense of beauty and tranquility, and so on. None of the individual components have these characteristics; they *emerge* only when the parts are combined into the complete object.

Even better examples of emergence arise when the components are combined in nonlinear ways. This is a fancy way of saying that the parts are not just added together, but merged in a more complex manner. Nonlinear combination is interesting because it can result in totally unexpected behaviors and characteristics. For example, suppose you had never seen fire, and one day you happen to encounter an unlit candle. Even in your wildest imagination you could not anticipate that this simple combination of parts could produce something as exquisite and complex as a candle flame. Again we find a case where the assembly appears to have something that is not contained in the components.

At first glance, one might think that emergence is contradictory to the method of reduction. After all, how can a

thing be reduced to its parts, if it is more than the sum of its parts? As we will see, reduction and emergence coexist without conflict, and are both important in science.

To understand how this works, suppose that our alien friends become tired of constructing hourglasses and want to experiment with something more interesting. We learn that the atmosphere of their planet does not contain oxygen, and therefore they have never seen fire. We suggest that the best way for them to learn about this new concept is to construct a burning candle. Accordingly, we transmit to them the position and state of each of the atoms in a lit candle, including those in the flame and surrounding air. Will the aliens be able to reconstruct the burning candle? Of course they will; they have everything that they need. The ability to "be a candle flame" is inherently contained in the properties of the Elements-of-reality, plus the assembly instructions. Nothing else is required. In the jargon of mathematics, these things are both necessary and sufficient to produce the object.

However, even though the aliens can construct a burning candle, they will not necessarily be able to understand it. For instance, consider what a human scientist would need to know to understand a candle flame. Being given the position and state of each and every atom would not be enough, simply because humans cannot analyze this type of raw data. The scientist would want to know something about the chemical reactions going on, the spectrum of the light being emitted, the patterns of air currents being generated, and so forth. While the Elements-of-reality plus the assembly instructions already contain all of this, it is not in a form that humans (or our alien friends) can directly understand. These ideas are illustrated in Fig. 2-4.

When we say, "the whole is more than the sum of the parts," we are referring to human understanding, not to what actually exists in nature. A super intelligent being may look at a candle flame and proclaim: "I understand it fully from the Elements-

FIGURE 2-4
Reduction versus emergence. Reduction guarantees that an alien could reconstruct a burning candle on his home world, given only the assembly instructions to do so. However, this does not mean that the alien would be able to understand it. Emergence is the process whereby humans (and presumably aliens) rearrange raw Information to create an *explanation*.

of-reality and the assembly instructions, and I need nothing more." Unfortunately, humans are not this smart; they require the Information to be rearranged and molded into a form they can more easily grasp. Just as a goldsmith shapes raw metal into fine jewelry, the scientist is an Information-smith, shaping raw Information into explanations.

It is human nature to think of a candle flame as being more than a mere assembly of components, a thing in itself, an entity existing on its own. And there is nothing wrong with this; it is an important tool for understanding the world. Just don't make the mistake of believing that these “mental entities” are more than they really are. They are a way of thinking about things, not residents of the external world.

In short, reduction is pure physics, an attempt to understand the nature of reality in its most basic form. In comparison,

emergence deals with how humans choose to understand that reality, blending physics with bits of philosophy, psychology, historical context, personal preferences, and so on. While emergence does not have the purity of reduction, it is a key part of science as well as our everyday lives, and humans would be able to understand very little without it.

The important point is that emergence deals only with Information, not Elements-of-reality. In other words, there is nothing that emergence can create that reduction cannot break apart. This means that reduction and emergence can be easily merged into a single framework for viewing the world. As shown in Fig. 2-5, this is done by adding another category next to the assembly instructions, something we call **Emergent Properties**. This is a broad and poorly defined depository for whatever explanations we need to understand the world. Of course, everything in this new category is redundant with what is already contained in the Elements-of-reality and the assembly instructions.

In the end, reduction plus emergence breaks the world into the same two types of things as reduction alone, (1) Elements-of-reality, and (2) Information. This brings us to the first major teaching of the Inner Light Theory:

Major Teaching #1:
How we Understand Reality

We understand reality through the methods of reduction and emergence. These methods divide reality into two categories: (1) Elements-of-reality, those things that are irreducible; and (2) Information, those things that can be transmitted over a communications channel.

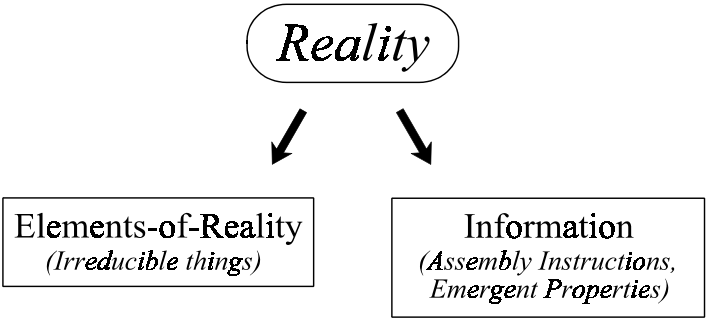

FIGURE 2-5
The endpoint of reduction plus emergence. Even when emergence is added to reduction, reality is still broken into the same two categories, Elements-of-reality, and Information.

Where Does Consciousness Fit In?

Science and our everyday commonsense are based on the methods of reduction and emergence. In turn, these methods tell us that everything that exists in reality can be divided into two categories, Elements-of-reality and Information. The obvious question is, into which of these two categories do we place consciousness?

As introduced in the last chapter, we can look at the mind from two different perspectives or positions. The first of these is from the outside, the objective world of science, what is often called the **third-person** viewpoint. As shown in the next chapter, the third-person view sees the mind as nothing but the operation of the brain, meaning that consciousness is pure *Information*.

The other way we can observe the mind is by introspection, where an individual turns his thoughts and scrutiny inward for self-examination. This is a view of the mind from the inside, a perspective referred to as the **first-person**. It is the personal and private way that we each see ourselves, the unique access we have to our own mental world. As we will discuss in

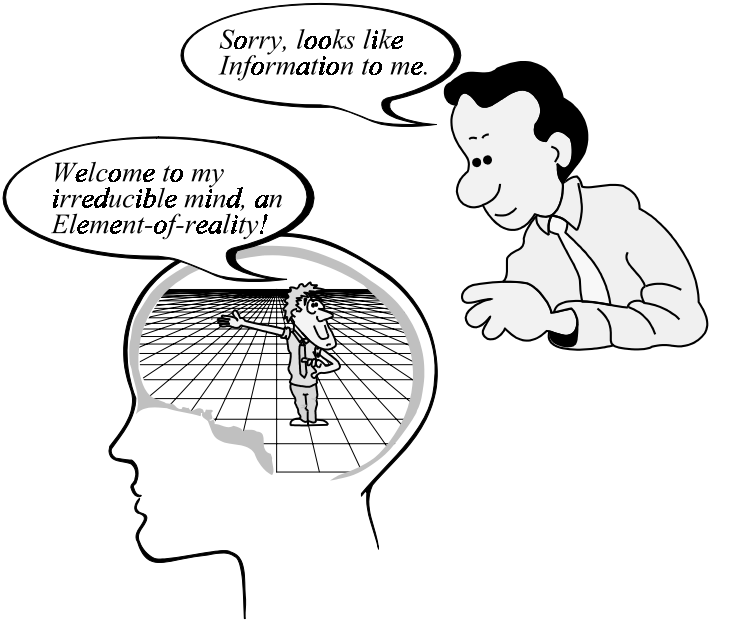

FIGURE 2-6
The mind-body paradox. The first-person perspective sees the mind as one or more Elements-of-reality, but to the third-person viewpoint it appears as pure Information.

Chapter 4, the first-person perspective sees the human mind as a unified entity, a thing in itself, something that cannot be broken into components. In other words, it is *irreducible*, and therefore consists of one or more *Elements-of-reality*.

This deep conflict is the heart of the mind-body problem, as illustrated in Fig. 2-6. From the third-person perspective the mind is *Information*, while from the first-person view it is one or more *Elements-of-reality*. Not only do the two viewpoints disagree, they disagree in the worst possible way. In the next three chapters we will look at these issues in detail.