# 1

## The Blind Spot

There are, indeed, things that cannot be put into words.
They make themselves manifest.
—Ludwig Wittgenstein[1]

Ludwig Wittgenstein was one of the great philosophers of our time, and yet the preceding statement is among his more obscure, especially when thought of in relation to science. In this case, he is saying that certain aspects of science, though real, cannot be put into words. Einstein understood this very well when he talked about his feeling that "behind anything that can be experienced there is something that the mind cannot grasp and whose beauty and sublimity reaches us only indirectly and as a feeble reflection."[2] The "blind spot" is my name for those things that are real but which the mind cannot grasp and thus cannot capture through words, symbols, or equations. I will now give some inkling of what Wittgenstein and Einstein were talking about, even though trying to use words to indicate that there is something beyond words is obviously a strange, not to say paradoxical, thing to do.

Let me begin with an old joke. A drunken man has lost his house keys and is searching for them under a streetlight. A policeman approaches and asks what he is doing.

"Looking for my keys," he says. "I lost them over there." And he points down the street.

"So why are you looking for them here?"

"Because the light here is so much better," the man replies.

The "light" refers to language, concepts, and reason. There is, for example the expression "the light of reason." "Darkness" would then rep-

resent the reality that lies behind conceptual language, reality in its pristine form—precisely what science is attempting to investigate. When you think about it, this is a little strange. We are trying to describe the darkness, but we do it by turning on the light. Of course, when you turn on the light, the darkness inevitably disappears. Darkness is a metaphor for the blind spot and, for this reason, the blind spot does not refer to some particular fact that cannot be put into words or some specific situation that cannot be understood. The blind spot is implicit in every situation.

Think about young children before they have learned to talk. I have a granddaughter, Aviva, who has just turned one. She is a delight—so interested in exploring her environment, so excited by her new experiences, the new textures to touch, new tastes, and so on. The world for her is a world of wonder! The blind spot refers to this world of wonder. Of course, as Aviva grows up, the immediacy of the sensory world will recede as she acquires verbal and intellectual skills, but it will never disappear. It will always be there, ready to reveal itself to her in one of those magical moments that occur from time to time in everyone's life.

I have borrowed the expression "blind spot" from the psychological phenomenon of the "blind spot" in our visual field. The *physiological blind spot* is the place in the visual field that corresponds to the lack of light-detecting photoreceptor cells on the optic disc of the retina where the optic nerve passes through it. Since there are no cells to detect light on the optic disc, a part of the field of vision is not perceived. The brain fills in with surrounding detail and with information from the other eye, so the blind spot is not normally perceived.[3] It seems incredible that our visual perception is incomplete in this way; it goes against our inner conviction that the world we perceive is coherent and complete. But the existence of the visual blind spot is a good metaphor for the ungraspable element that we confront when we attempt to probe the natural world in our scientific work. Just as our brain provides us with the illusion that there is no visual blind spot, so our rational intelligence—through its insistence on consistency and completeness—hides the blind spot from our consciousness.

Another scientific metaphor for the blind spot is the phenomenon of the black hole, a "region of space-time from which nothing, not even light, can escape. A typical black hole is the result of the gravitational force becoming so strong that one would have to travel faster than light to escape its pull."[4] Because black holes exist but cannot be seen, they are

a good way to think about the blind spot. Black holes contain singularities at their centers, points at which the equations of general relativity break down. These singularities are mysterious objects. Are they real or do they merely indicate a breakdown in a particular theory? Any physical theory that attempts to put together quantum mechanics and relativity will have to deal with the phenomena of black holes and singularities. I would argue that the relationship of black holes to a fundamental physical description of the world is analogous to the relationship of the blind spot to a fundamental philosophical description of science.

The experience of suddenly becoming aware of what was formerly a blind spot is shocking and disturbing. Consider the experience of the blind spot in your car. You decide to change lanes and so check your rearview mirror to make sure you have plenty of room to merge into the oncoming traffic. However, just as you start your move, a car you were not aware of, pops up, seemingly from nowhere. This is an experience every driver has had. It is disconcerting and a little embarrassing. Why? Because we realize with a shock that the mental picture we had of the cars on the highway is not identical to the actual situation. It takes a while to settle down again and regain confidence in the accuracy of our mental map.

The preceding metaphors and analogies have something to teach us about our scientific descriptions of the natural world. All such descriptions have inevitable spots that we are blind to precisely because it is the function of language and culture to hide them. Consider something that Stuart Kauffman, the theoretical biologist and complex systems researcher, said,

> My claim is not simply that we lack sufficient knowledge or wisdom to predict the future evolution of the biosphere, economy, or human culture. It is that these things are *inherently* beyond prediction. Not even the most powerful computer imaginable can make a compact description in advance of the regularities of these processes. There is no such description beforehand. Thus the very concept of a natural law is inadequate for much of reality.[5]

The statements of Wittgenstein and Kauffman contain the seeds of a different view of science, one that admits that there exists an intrinsic limitation to what can be known through science. It places science within a more open and spacious context and sets the stage for this chapter.

The existence of that which is real but cannot be understood poses a major challenge to our usual way of thinking about the world and to our thinking about the relationship between human beings and the natural world. Ask yourself if you believe that there are things that cannot, in principle, be understood. Your answer will tell you a great deal about yourself! The discovery of such "limits to reason" is in many ways the key scientific discovery of the twentieth century, one that our society has still not fully assimilated. I shall go into specifics in the next chapter but for now let me just say that it is this factor that explains the controversial nature of a good deal of modern mathematics and physics. I am thinking about Cantor's discovery of different orders of infinity; Gödel's proof that within any deductive system there are results that are true but cannot be proved; about the second law of thermodynamics that states the amount of disorder within a system must always increase; about uncertainty and complementarity in quantum mechanics; about the "butterfly effect" in the theory of chaotic systems, which says that every small change in the initial conditions of a system can have an enormous effect on its eventual state; and about randomness that seems to show up just about everywhere, from the theory of evolution to the fluctuations of the stock market. All of these point to intrinsic limitations in our ability to pin down reality in concepts and symbols. This is a key ingredient in the approach to science and mathematics that I am taking in this book, an approach that attempts to come to grips with the element of self-reference that is inevitably part of any attempt to describe the world as a living system.

## ON DEFINITION

> I think that there is such a thing as Quality, but as soon as you try to define it, something goes haywire. You can't do it.
> —Robert Pirsig[6]

What is a definition? In science, we usually think that a concept is captured by means of a definition. It makes the concept precise; it circumscribes the concept; it sets limits so we can now say precisely what is and what is not an instance of the concept. Such precision through definition

is a necessary condition for a subject to be regarded as scientific. Without this kind of precision it would be difficult to imagine the process of measurement and quantification getting started. If I ask what a (mathematical) group is, the answer is a set whose elements can be multiplied in some reasonable way subject to some very specific requirements. The concept *is* its definition. Yet, as we shall see, many mathematical and scientific concepts point to something that is deeper, more all encompassing, than their definitions. Some things cannot be put into words because doing so is only an approximation to the real situation. The verbal or symbolic formulation captures some aspects of the situation but is not identical to it. There is a question regarding the relationship between the definition and the thing being defined.

To really grasp the essence of the problem with definition, one must go back to the Ancient Greeks. The Greek philosopher Parmenides is reputed to have maintained that you can only speak of what is, "what is not cannot be thought of and what cannot be thought of cannot be." It followed from this attitude that (absolute) "infinity" or even "zero" could not be defined because they "could not be." This attitude is a philosophical precursor to the "naïve realism" of today: the sense that the proper role of language is to enter into a one-to-one correspondence with the objects of the real world. It is a sensible reaction to the complexities of language. At first glance, it seems entirely reasonable to insist on a one-to-one correspondence between words and reality. Why? Because it protects us from the self-referential spiral that is inherent in human self-consciousness, the ambiguity that lies at the heart of the human condition that I shall discuss in subsequent chapters.

The problem of the relationship between language and reality is a problem that has been around for a long time. It is a vital problem, since without a clear notion of the nature of "definition" we cannot really begin to study mathematics or science. This question is a primordial one for any philosophy of science.

Is it always possible to keep the definition of a concept consistent with its meaning? Think about "zero." Zero represents "nothing," yet "zero" is not nothing—it is a digit, a number we use every day. The definition of "zero" is inconsistent with the meaning of zero. We can see why the Greeks could not entertain the idea of "zero," yet their math and science was the poorer for this omission.

Or take the concept of infinity. Infinity (in-finity) means non-finite, the essence of infinity is that it cannot be captured by the finite. Yet that is precisely what defining infinity does—it reduces infinity to something that is finite and manageable.[7] Again, the concept does not jibe with the meaning. This twist in infinity is the reason that infinity caused so much trouble historically[8] and remains a prime difficulty for students of mathematics. It was at the origin of the Greeks' attempt to distinguish between "potential infinity," which they felt was acceptable, and "absolute infinity," which they rejected. Potential infinity is essentially infinity as a process—for example, when you say that for every large number A and every small positive number ε there is an integer n such that $n\varepsilon > A$. Absolute infinity means treating an infinite collection as though it was one completed object, like when we treat an infinite decimal such as 0.121212 … as a single (real) number. The reason for the Greeks' rejection of absolute infinity was the one I gave earlier: any definition of absolute infinity would be inconsistent with the meaning of infinity.

This problem with infinity was at the origin of the controversy that arose concerning the work of Georg Cantor. He claimed to have defined (absolute) infinity, which most mathematicians of the time claimed could not be done *in principle*. Of course, what Cantor had done was reduce infinity into something that was *defined*, which was circumscribed and manageable. This is what it means to define something so it can be worked with mathematically or scientifically—something that one can understand, that has definite properties and is a potential source of theorems and examples. Nevertheless, the Greek problem with absolute infinity was not resolved by Cantor's definition, nor will it ever be by any other.

The difference between definition and meaning may be clarified by differentiating between what is called the denoted meaning and the connoted meaning. The definition *is* the denoted meaning, but the (larger) meaning includes the open-ended collection of possible connotations.

In *How Mathematicians Think*, I listed a whole series of mathematical concepts that contained variations of this twist. I called them "Great Ideas" because I feel that this twist (or ambiguity) has great value. Great ideas include things like randomness, zero, and irrational numbers. In a way, all great ideas cannot be pinned down definitively because they all contain variations of the problem that is present in the idea of infinity. Take randomness, for example. Gregory Chaitin wrote[9]

> Borel's conclusion is that there can be no one definitive definition of randomness. You can't define an all-inclusive notion of randomness. Randomness is a slippery concept, there's something paradoxical about it, it's hard to grasp. It's all a matter of how much we want to demand. You have to decide on a cut-off, you have to say "enough," let's take *that* to be random.

It is not that randomness cannot be defined. On the contrary, defining randomness has great value; it is a huge creative accomplishment. Nevertheless, there remains an inevitable gap between the definition and what is being defined. Identifying the definition with what is being defined may cause us to lose touch with the openness, the incompleteness, of the original situation. The original situation, which may well have contained elements of ambiguity, and even of paradox, that gave birth to the definition, now disappears, to be replaced by a new situation with its own problems and creative possibilities.

One might imagine that the gap between the deeper meaning and the explicit definition, the sense in which mathematical situations cannot be defined or understood, is exceptional. However it is present in every formal mathematical structure that inevitably contains undefined terms. Here is what mathematician Marvin Jay Greenberg has to say about Euclidean geometry:

> … we cannot define every term that we use. In order to define one term we must use other terms … if we were not allowed to leave some terms undefined we would get involved in infinite regress.
>
> Euclid did attempt to define all geometric terms. He defined a "straight line" to be "that which lies evenly with all the points on itself." This definition is not very useful: to understand it you must already have an image of a line. So it is better to take "line" as an undefined term.[10]

Greenberg goes on to list undefined terms in plane Euclidean geometry: *point*, *line*, *lie on* (a point "lies on" a line), *between* (the point A lies "between" the points B and C), and *congruent*. This is the modern approach to developing an axiomatic system. Some basic ideas must remain undefined. We cannot pin down everything—there always remains a certain incompleteness.

Even ordinary mathematical ideas share, to a certain extent, this problem with definition and, as a result, we shall have to learn to think about definitions in a new way. Take, for example, the idea of "number." What is a number? It is scarcely possible to define "number"—it is so basic and elementary. The German mathematician, logician, and philosopher, Friedrich Ludwig Gottlob Frege, tried to show that the idea of number could be developed starting with the idea of "set." The idea was to establish a firm foundation for all of mathematics. His attempt ultimately failed because of the discovery of certain paradoxes that arise when one thinks of a set in a naïve way as just a collection of objects. But that is not the main problem with this kind of approach. The problem is that such reductionism causes us to lose touch with the very thing we are interested in understanding—here, the nature of "number," the deepest and most important source of mathematics. The fact that "number" can or cannot be developed from some other concept does not necessarily help us in our attempt to understand and explore "number." In a sense, number cannot be defined, and yet to leave it at that is somehow also dissatisfying. "Number" evokes a whole universe, an entire manner of looking at the world, which I shall discuss in some depth in chapter 7. This universe can only be explored, not captured. Every deep mathematical or scientific idea, like the idea of number,[11] evokes a whole world. Some of these situations have a consensual meaning—integers, rational numbers. Some, like real numbers, are more complicated. But mathematics contains many different kinds of numbers and there is no intrinsic limit to the capacity of mathematicians to produce new kinds of numbers in the future.

Trying to understand something often means trying to give it a definition, yet (as in the case of infinity or randomness) another definition is always possible. Each definition structures a certain field of mathematical or scientific thought. Certainly one definition may be better than another but even an excellent definition does not capture the informal domain out of which it emerges. It structures the informal situation. When we use the word definition, we are usually referring to this formalized version, and yet understanding a given situation necessitates the integration of both levels—the formal and the informal. You could say that it is impossible to understand the informal, but the formal situation also has its difficulties. "Understanding" demands placing something in a

context. It implies having a "feel" for the situation in which the concept arises, not to mention the ability to use the concept in novel situations or solve problems not previously encountered. You cannot understand a definition by parsing it. You acquire an understanding by working with the definition in many different circumstances, by thinking about it, by solving problems involving the concept, and by making mistakes and learning from those mistakes. Understanding is a process without end. At a certain stage in the process, one can say, "I understand randomness." But in reality you can always understand it better, understand it differently. The better you understand it, the more grounded you are in the primal notion. Randomness is not a thing. In a way, it does not exist; it is open and inevitably incomplete. Yet every formal definition of randomness produces its own reality that needs to be understood.

All interesting and important concepts have definitions with this kind of depth. An explicit formulation is not *the* definition but should be thought of as an "entry point," the beginning of an exploration. We then work with this (tentative) definition trying to expand our understanding. We do this by exploring in two directions simultaneously—backward by evoking the informal situation out of which it arose, forward by exploring examples and consequences. In the process of this exploration, our understanding will be expanded and made subtler. This process may then be iterated a number of times. Each subject we explore should be thought of more as a "field" (like an energy field in physics) than a fixed and definite object. A field does not have a fixed objective meaning. It is much much larger than that.

## THE UNGRASPABLE

The conclusion of the previous discussion is that, in the deepest and most profound sense, the things that make up the world cannot be defined, nor can they be understood or pinned down in any definitive way. This is the gap that has emerged in the order of things, a gap and a challenge that has the most profound implications for how we conceptualize the entire scientific enterprise. I'll refer to this gap by speaking of the ungraspable.

Science is a way of approaching the world; it consists of asking nature certain kinds of questions and of obtaining certain kinds of responses.

The entire world of science is grounded in human consciousness and rationality. In science, the world is described in a specific way, using a certain kind of language—and so reality is reduced to rationality. How accurate is the picture of reality obtained through science? The existence of the "ungraspable" implies that there are intrinsic limitations to the cultural project of reducing reality to rationality. In a manner that is paradoxical yet consistent with the lessons of scientific progress in the last century, I shall base my critique of science on recent developments in science itself.

## Blindsight

*The New York Times* recently carried an article written by Benedict Carey about a man, T. N., who had been left blind by two successive strokes yet was able to successfully navigate a cluttered hallway full of potential obstacles. Brain scans showed that the patient had no visual activity in the brain's cortex—he was profoundly blind—yet he saw. How was that possible? "Scientists have long known that the brain digests what comes through the eyes using two sets of circuits. Cells in the retina project not only to the visual cortex—the destroyed regions in this man—but also to subcortical areas, which in T. N. were intact." Most people are not aware that they possess these alternative resources for processing visual information. In fact, Beatrice de Gelder, a neuroscientist at Harvard and Tilburg Universities and the researcher involved with this experiment, said, "The more educated people are, in my experience, the less likely they are to believe they have these resources that they are not aware of to avoid obstacles." The patient, a doctor, was dumbfounded that he could navigate the obstacle course.

I bring up this experiment because it has implications for our discussion of the ungraspable. To grasp something usually means to integrate it into our normal conscious rational view of things. The essence of what is going on here is that what has been eradicated is what you could call "conscious sight," the normal sight of the visual cortex. Because the visual cortex was destroyed, it became possible to bring subcortical faculties into conscious awareness and possibly restore some partial visual capacity to T. N. Perhaps we also normally think of science as though it were a function of only a certain part of the brain. We have other facul-

ties that are at play in our interactions with the world but they are not normally accessible to our conscious self and therefore often do not show up on our scientific radar screen.

## GUT FEELINGS

The next example comes from some studies in 1997 led by Antoine Bechara and Antonio Damasio as described in the book, *The Mind and the Brain*.[12]

> Volunteers play[ed] a sort of gambling game using four decks of cards and $2,000 in play money. All the cards in the first and second decks brought either a large payoff or a large loss … cards in decks 3 and 4 produced … small risk, small reward. But the decks were stacked: the cards in decks 3 and 4 yielded, on balance, a positive payoff. That is, players who chose from decks 3 and 4 would, over time, come out ahead.… A player who chose from the first two decks more than the second two would lose his (virtual) shirt.
>
> Normal volunteers start the game by sampling from each of the four decks. After playing for a while, they began to generate what are called anticipatory skin conductance responses when they are about to select a card from the losing decks. This skin response occurred even when the player could not verbalize why decks 1 and 2 made him nervous. Patients with damage to the inferior prefrontal cortex, however, played the game differently. They neither generated skin conductance response in anticipation of drawing from the risky decks, nor shied away from these decks.
>
> Bechara and Damasio suggest that, since normal volunteers avoided the bad decks even before they had conceptualized the reason but after their skin response showed anxiety about those decks, something in the brain was acting as a sort of intuition generator. Remarkably, the normal players who were never able to figure out, or at least articulate, why two of the decks were chronic losers still began to avoid them. *Intuition, or gut feeling, turned out to be a more dependable guide than reason.* [italics added] It was also more potent than reason: half the subjects with damage to the

inferior prefrontal cortex eventually figured out why, in the long run, decks 1 and 2 led to net losses and 3 and 4 to net wins. Even so, amazingly, they kept choosing from the bad decks.

The point of this story is again that people have capacities that they cannot bring into everyday verbal consciousness. Even though we can talk about these "gut-feelings," this does not really mean we are "grasping" the intuitive sense. Bringing intuition into consciousness means translating it into another mode of awareness and so changes the original "gut-feeling" into something totally different. It even involves shifting from one region of the brain to another. In this sense, our "gut-feelings" are ungraspable.[13]

The same phenomenon often occurs to me when I write. I may have read some article or had a discussion and I have a gut feeling that there is something there that is relevant to what I am writing about. At this stage, I'm not sure what the relevance is exactly but I begin to write it down and integrate it into the chapter I am working on. More often than not I eventually get something coherent down on the page. When I reread it, I may say to myself, "Ah! That's what I was trying to say." Yet at the stage of the inarticulate gut feeling, my rational self does not understand what I want to say; what I shall end up saying exists but has not yet been grasped.

## "Stunned by What Is but What Cannot Be Put into Words"

Now the previous two sections can be taken in various ways. One could conclude that everything can potentially be integrated into rational consciousness and that this is the definitive mode of being in the world that corresponds to the way things are. That is not what I am saying. My position is that *what* is understood cannot be definitively separated from the mental facilities through which we understand. Grasping some topic or situation refers to a particular way of interacting with it. Inevitably, aspects of the world cannot be grasped in principle. This ungraspable nature of things does not only refer to gut feelings or blindsight. It is also a feature of our normal scientific conceptual universe. The ungraspable refers to a quality of intrinsic incompleteness that is inevitably associated with the conceptual.

Many people will be surprised by the assertion that some things cannot be understood. These people inhabit what I will call the "culture of certainty," who imagine that science proceeds by totally mastering some particular aspect of reality before moving on to the next bit in the way an army conquers foreign terrain. The "army" in this case would be rationality itself. If some aspects of reality cannot really be grasped, then science never conquers any territory. It explores territory, but even a territory that has been well understood may yield additional surprises if it is approached from a novel point of view—everything can potentially be understood at a more profound level. What we understand at any given moment in time can be thought of as a two-dimensional surface. The third dimension in this metaphor consists of the depth that potentially can be brought to the situation.

The realization that things cannot be grasped may be seen as either a disaster or an opportunity. It is not necessarily a problem unless you make it into one. The opportunity it represents involves opening oneself up to a world that is alive and vital—a world of wonder. It has these characteristics *because* the world is not pinned down, stable, and totally predictable. Remember when I say that the world has this potential that I am simultaneously saying each one of us also has this potential. We are also evolving, alive, open, and vital! Without what I am calling the ungraspable, there is no awe or wonder and everything is smaller and less interesting.

This brings to mind a statement by the philosopher Abraham Heschel:

> What characterizes man is not only his ability to develop words and symbols, but also his being compelled to draw a distinction between what is utterable and the unutterable, to be stunned by what is but what cannot be put into words.[14]

Heschel's statement provides me with the opportunity of saying something about all of those aspects of our personal and professional lives that have the same inescapable incompleteness I have been discussing. Everything we have talked about in this chapter can be construed both negatively and positively. Negatively, we are putting limitations on what can be understood. Positively, we are saying that what we are referring to exists. We are stunned by "what is but cannot be put into words." To take a step in the direction of the unknown, to look at science

and mathematics from this point of view, is to begin the process of healing the rupture within ourselves and within our culture that has caused and continues to cause so much damage.

Randomness exists, but what it is, its essence, cannot be grasped in words. The reason for this anomaly is that randomness is paradoxical—it has the same sort of gap we discerned in our discussion of zero or infinity. I tried to capture this paradox in the following parody of an Aristotelian syllogism:[15] "Mathematics is the study of pattern. Randomness is the absence of pattern. Mathematics studies randomness." But even concepts like number or continuity that are not paradoxical have an ineffable core. I shall pursue this more in chapter 7 when I talk about the difference between concepts and what I call proto-concepts. The ungraspable essence of things is what Heschel is pointing to. That which is real but inexpressible is not something vague or mystical; it is something that is immediate and simple. It is the ground out of which the concept arises. It is "nothing" but not zero; it is "infinity" but not infinite cardinal numbers; it is "time" but not the real variable "t" or even the fourth dimension of Einstein's space-time continuum.

## CONCLUSION

Science derives from a source that is not accessible to science. At first glance, this statement seems so strange that one has to resist the temptation to reject it out of hand. Yet many people have had precisely the same intuition, even the same experience, in certain moments of creative insight. What creative worker in any field has not had the feeling that the sources of creativity are inaccessible to the conscious mind? It is the fear of blocking the creative source that accounts for the reluctance on many people's parts to analyze their own creative process. A mystery underlies the creative process, and this mystery is its very essence. Calling it a mystery does not mean the sources of insight do not exist or that they are "mystical" and thus unreal. Calling it a mystery means the sources are inaccessible to the everyday conceptual mind. When you look toward the unknown, which is what you do in scientific work, it is evident that one will see a kind of "blankness" or absence of structure. If the scientist can solve the problem by conventional means or by merely rearranging

previously well-established elements, then it would not be necessary to descend into the unknown. The known must be exhausted before one is forced to confront the unknown. The sources of creativity are by definition unknown, inevitably outside of the present conceptual universe, since the conceptual universe is itself the result of acts of creativity.

The unknown is the matrix out of which creativity is born. The birth of creativity, the dawning of insight, is wonderful but unpredictable. One can work hard but that does not guarantee success. One can prepare for it but one cannot program it nor anticipate when or in what form it will eventually appear. Creativity has its origins neither in the natural world nor in the world of concepts—it involves much more than the mere shuffling of well-defined conceptual categories as a computer would do. Where do new concepts come from? If anything, concepts are the results of acts of creativity and not the other way around.

Clearly, a philosophy of science must begin with what is real. However, science is not identical to reality; science is a description of reality. The basic difference is what I meant by the difference between darkness and light at the beginning of this chapter. What we need to do is investigate the relationship between the description and the reality that stands behind it. The first thing that is necessary is to break the mistaken identification of science with reality. Of course, science is not arbitrary; it has a profound relationship with what it describes. Nevertheless, science is not to be equated with the real. This is a statement that is completely obvious yet bears repeating since it is necessary to differentiate between science and the mythology of science, between what science actually does and the story that is told about it. Just as the brain renders invisible the physiological blind spot and gives the illusion that the visual field is continuous and complete, so the mythology of science has the function of hiding from view the holes in the fields of consciousness and rationality. So, like the child viewing the emperor's new clothes, it is necessary to point out this blind spot.

I attempted to do this by talking about the "ungraspable," but the danger is that one thinks of the ungraspable as something divorced from reality. The "blind spot" I am talking about is an inevitable consequence of our rational consciousness. We are aware of it as a lack, but when we turn our conscious mind to it, it inevitably disappears. Yet we can infer the existence of this domain by making a small shift in the way we look

at things. The development of science in the last century contains many instances of the discovery and the rediscovery of this phenomenon under a plethora of different guises—ambiguities, paradoxes, incompleteness, complementarity, randomness, and so on. Are they not all, in one way or another, blind spots? And what is the assumption of rationality, the assumption of logical consistency if not the mind's way of "filling in" the holes in our rational universe. When we look for this blind spot intellectually, it seems to disappear and so we must infer its existence in an indirect manner. Nevertheless, we *know* that our intellectual world of thought and reason is not all there is. Anyone who is engaged in creative work in the arts or sciences appreciates that creativity does not arise from reason alone. Its ultimate sources are ungraspable.

It always comes as a shock to realize that one's view of things is inadequate. As I mentioned in my discussion of the driver's blind spot, the realization that a blind spot exists can lead to a certain anxiety, the kind that people feel during an earthquake when you cannot rely on the stability of the earth beneath you. Yet when one attempts to plumb the depths of scientific thought to its very origins, one inevitably encounters this phenomenon that is extraordinarily difficult to explain or describe. It is immediately rejected by the rational mind, the point of view from which science is usually discussed. Thus, discussions of science and even the philosophy of science are usually after-the-fact rational reconstructions of science. Yet rationality is itself the result of an act of creativity and so cannot be used to explain the origins of the extraordinary creativity of science. Nevertheless, I maintain that without making this attempt to plumb the deep sources of scientific creativity we doom ourselves to a pallid superficial description of the scientific enterprise. We will miss the essence of science and the consequences will be grave, for it is our understanding of scientific culture that today determines what we think is real, not only in the natural world but also in ourselves. To put it bluntly, are we sophisticated machines or are we free open beings whose birthright is a kind of unlimited creativity? These are the stakes and I cannot stress too highly the importance of the view we hold of science, and as a consequence the view we have of what it means to be human.