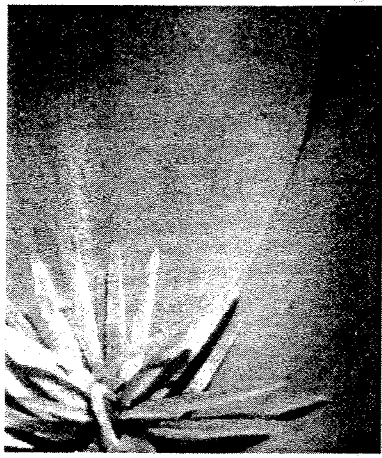
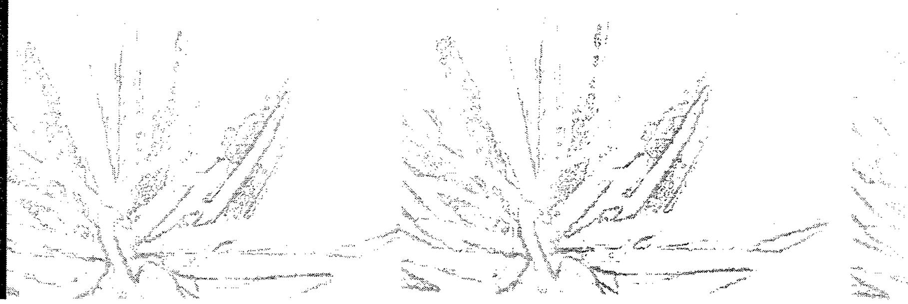




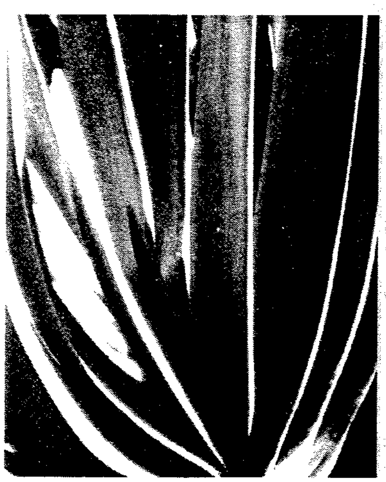
Contemplating Nature

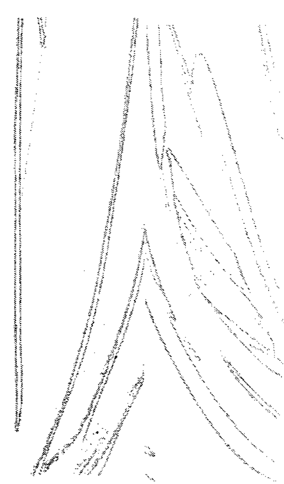
with
Arthur Zajonc

Interviewed by
Jane Clark

Arthur Zajonc, Professor of Physics at Amherst College, Massachusetts, is a man with an unusually broad perspective on science. A successful researcher who has been involved with some of the most thought-provoking experiments of recent times—investigating the very foundations of quantum mechanics—he has also had a long-standing interest in spirituality and studied the work of Rudolf Steiner in depth. He believes that "science is not apart from life, but part of it", and brings aspects of myth and legend, history and philosophy to his teaching and writing—an approach which one suspects will bring him a large public when he publishes his first book next year. Entitled Catching the Light: The Entwined History of Light and Mind, *it is a comprehensive account of the history of light, from the ancient past to contemporary discussion, from spiritual symbol to scientific phenomenon*.*

He has also been fascinated by the process of education, founding, with his wife when their children were young, a Waldorf school which has since grown to be a thriving concern with nearly 200 children. More recently, he has become interested in science museums, working with the Holyoke and Boston Children's Museums and the Tampa Museum of Science and Industry in Florida to develop new approaches to exhibiting which will "not only show the bells and whistles of scientific achievement, but also give people an opportunity to encounter beauty and explore the values and ethics of their civilization through an 'ecology of exhibits'."





For Zajonc, science is pre-eminently a practical activity; a way of bringing about, in a systemized way, a personal encounter with nature. "In doing," he

photographs by Bambi Rhodes

*Bantam, due to appear in February 1993.

has said, "you form yourself, and what you form yourself on determines the faculties you create." Born in 1949 into a family which brought together a Polish immigrant (hence the perplexing name, which is pronounced Zy [rhymes with "sky"]-ons [rhymes with "mons" as in "monsoon"]) with an old established American family, his own interest in physics was born of a love of tinkering with machinery, taking things apart and putting them back together. He studied engineering at the University of Michigan, then moved over to physics in graduate school. He was attracted by the purity and clarity of its mathematical approach, but nevertheless became an experimentalist rather than a theoretician, working on atomic scattering, and then in the new and exciting field of laser optics. This led him, in 1978, to Amherst College, where he rose to become Chairman of the Department from 1987-9 and a Professor in 1991.

*His interest in spiritual and philosophical matters began at graduate school, where he was introduced to the ideas of the German thinker Johann Wolfgang von Goethe. Known mostly now for his impressive literary achievements (*Faust *is perhaps his most famous work) Goethe (1749-1832) dedicated much of his later life to science, and developed a methodology radically different from the mainstream tradition. For him, too, science was preeminently a practical activity, concerned with the active perception and witnessing of phenomena in their wholeness rather than with mathematical abstractions. His approach, dubbed "rational empiricism", was developed further by Rudolf Steiner, whose work, scientific and other, Arthur began to study in earnest during the 1970s.*

But it was not until 1981, while on a year's sabbatical in Paris, that Zajonc began to think seriously about how he could bring together his spiritual and scientific interests. He started to look out for physics problems which seemed particularly open to philosophical enquiry, and found that there were several groups of scientists in Europe and America working on a new experimental approach to quantum mechanics. Knowing this was a field in which "there were many curious and wonderful issues which tended not to be given much time in orthodox physics", he entered into correspondence and eventually joined a team in Munich which was setting up experiments to investigate wave/particle duality in light. Since then, he has worked on similar experiments with another team at the University of Rochester, New York, led by L. Mandel, and in his own ongoing research at Amherst. Next year he will be a Fulbright Professor at the University of Innsbruck where he will teach and research on the foundations of quantum mechanics.

The importance of these experiments, Zajonc believes, is that they reveal aspects of nature which are incomprehensible within our present conceptual frameworks. There are other problems which are pushing us toward the same conclusion—the immense social and political problems we face globally, the ecological crisis, etc.—and all these are, somehow, intimately linked. "If we would create the capacities for understanding our future," he has said, "we must dwell precisely in the tensions and the paradoxes—the annoying anomalies—of our time." It was these "annoying anomalies", as they appear in the physics laboratory, that we discussed last November in San Francisco following an Institute of Noetic Sciences meeting on Causality Issues in Science.

—Jane Clark

The Interview:

Jane: Can we begin by talking about some of the work you have been doing on quantum mechanics; the experiments you have been involved in?

Arthur: Abner Shimony of Boston University, who is one of the world's best philosophers of science, has called this work "experimental metaphysics". These experiments are designed to give us an insight into the way in which the world is built up—the way it is made. There are a good many of them now, falling into different classes, and each of them represents a subtle side to the world which by and large we have tended to overlook. You see, there has been a great tendency in our culture since the time of Descartes and Newton to see the world in terms of discrete and separable sub-systems—atoms, or fundamental particles or whatever. This is a very logical way to think, and it corresponds in many ways to things that we see all around us in the world. When we build a house we build it one brick at a time, and when we step inside the final construction, we can still see the bricks. But it seems that there are other parts of the world which are not built up like that. In particular, the structure of the quantum world seems to be such that, once quantum mechanical objects come into conjunction with one another, the bricks sort of dissolve away, and, at least under certain circumstances, are just not there anymore. So it seems that we have to get away from this idea of bricks juxtaposed to one another, and create a new idea, a new conception of the way that the world is ordered. And the way that we have come to talk about this in physics, in the language of quantum mechanics, is as a "quantum superposition" of states, or as Schrödinger more descriptively termed them: "entangled states".

Jane: I'm sure that makes a lot of sense to someone who has studied quantum mechanics for many years; but can you say more about what this really means in lay terms?

Arthur: The most famous experiment that has been done is perhaps the one which Alain Aspect did in Paris in 1982. It is referred to as the "EPR" experiment because it is based on a thought experiment proposed during the 1930s by Einstein, Podolosky and Rosen. In this experiment, two particles which were originally isolated—two bricks if you will—come together and interact. It is as if all of a sudden there is mortar between them. They go along together for a while, and then they fly apart. And the surprising thing, which Aspect showed in his measurements, is that even after they have separated, their behavior remains linked; there is some mysterious, "non-local" connection between them.

One way of understanding what is happening in the experiment is that when the two objects meet, they become a single new object. And if we are going to think about this object in classical terms, then we are led to say that it must include, in some way, two states of the original objects, which are "superposed", one on top of the other. Now the interesting thing about the EPR experiment is that the original "bricks" are in opposite states from one another; their spins are anti-parallel, which means that they are thought of as "spinning" in opposite directions. So when they come together and interact, we have to postulate that the new object that they become contains *both* sorts of spins. That is, we have an object which contains, within itself, logically opposite properties—which seems like nonsense.

I want to emphasize that the reason we must postulate this is because of the experimental outcomes. In other words, this is not only a convenient way of thinking about things, which we could do without if only we understood what is happening at a deeper level—which was the position that Einstein took on quantum mechanics. The results of the experiments themselves, which are coherent and consistent; the measuring processes which are performed; the interferences which are detected—none of these would be as they are without this "superposition" of states *really* being present.

Jane: The Aspect experiments have become very well-known now, but I think some of the ones you have worked on are not yet common currency.

Arthur: The experiment I have been working on, "The Delayed Choice Experiment" (see diagram, page 23), shows a similar union of opposites, but it deals not with two particles but with one—a single quantum of light, or "photon". Here, the opposition is not between two spin orientations, but between two opposing properties of light—the wave and the particle. And we find that we have to postulate that the photon has, in itself, properties which are both wave-like and particle-like: that there is a superposition state present in which it travels down one path *and* it travels down both paths at the same time. Now we don't have an adequate classical concept for this; and yet this inadequacy, because of the delayed choice, propagates all the way through the apparatus.

Jane: One of the ways I have heard the Delayed Choice Experiment discussed is that it would appear to show that the act of observation—the measurement—is determining retrospectively how the particle behaves.

Arthur: That is the way that John Wheeler would have put it. But one must be careful of the language here; what *appears* to take place is that a measurement in the moment, now, determines what has already taken place in the past. Because the photon has already gone through the beam-splitter. In our case, the apparatus is only 3-4 meters of optical fiber, but, in principle, the distance could be that to some distant star—which is an example that Wheeler uses in one of his speculative experiments. So the distance doesn't matter, nor the time—for the photon can be en route for many years. Yet the observation still seems to determine whether it travels as a particle or as a wave.

But we should be clear about what we are saying here. What I would not say, and I don't believe that Wheeler would either, is that the present *actually* influences the past. But it appears to. And this tells us that the way that we think about light is wrong; that if we insist on bringing classical concepts of either waves or particles into quantum mechanics—thinking of them as ping-pong balls or waves on the ocean—we are going to get ourselves into a bind.

So the problem is not with our notions of space and time—there are other problems with those—but with our ideas about light. If we adopt the right concepts about light, which is what quantum mechanics does, there is no problem.

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Jane: What other problems with space and time?

Arthur: Well, one tends to think about superposition as occurring only for spatial effects, but it has been recently proposed by Franson at Johns Hopkins University that it could also apply to temporal orderings. And Mandel and others have begun to do these experiments, and achieved just the kind of results that startle you.

The experiments are based on the fact that, in quantum physics, you often have two possibilities for temporal ordering. Let me give you an analogue rather than a technical description. Imagine that you and I leave the apartment here. We are going to meet at a designated place—the Exploratorium. Now to get there, we could each go directly, or we could take a detour. The detours will add an extra element to the time it takes to get there, but we will still arrive within a "window" of time—a certain span during which someone else could see us there, and observe us together. We could do a calculation which considers the time sequences, the ordering, of the situation. There are some easy options; say, I go direct and you take a detour, in which case I will arrive first and you last. Or you go direct and I take a detour, in which case you arrive first. Et cetera.

These experiments show that the structure of time and space is more complicated than we thought.

Now there is a particular set of phenomena, which are interference effects, which require not that I get there first and you after, or you get there first and me after, but that both of the above must occur, that is, that you get there before me and I get there before you. This is a temporal superposition state; it contains logically opposite attributes.

Jane: These effects have been experimentally confirmed to be true; they really happen?

Arthur: Yes. These experiments have been done; this effect occurs. And what they show, I think, is that time ordering is much more ambiguous than people assume. This is something that was always known in high-energy particle physics; that if you wanted to get proper results, then there were, for very short periods of time, these ambiguities about time ordering. But now these effects have been shown to happen in laboratory situations, using common manipulations of light. So the structure of time and space is more complicated than we thought; quantum mechanics has really done that.

Jane: So what difference do these experiments make? I mean, wave particle duality and such like have been known since the beginnings of quantum mechanics, and people have been discussing them ever since.

Arthur: The interest, to me, is in the possibilities for education. It's true that all these effects are predictable; so that to explain them, we don't have to invent a whole new theory and get a Nobel prize or whatever. But what they demand is that we pay closer attention to the theory that we have, and what it means. And to the experiments, because they are surprising—surprising in themselves, as phenomena.

A parallel, perhaps—a dramatic one—is that everyone knows that at some point in their lives, they are going to die. This can be predicted with 100% certainty; I and everyone I care about will die. But it is a different matter when it actually happens. And when someone close to you dies, it can be a profound and transformative experience. This is a very vivid and graphic example of how a predictable event can nevertheless have a profound effect.

A much less vivid, but perhaps parallel one, is to be in a room with optical equipment and a calculation which tells you that these quantum superposition states are important; and to try to think through the experiment from beginning to end, as you have been accustomed to in every experimental situation you have ever come across, step and step. And you suddenly realize that your classical ideas are not going to work. But nevertheless, something has happened; this is not just a theory, put together with paper and pencil. Here is apparatus which requires, for its running, some new idea. And this new idea has a mathematical expression, but it is one which is opaque to common-sense intuition.

It seems to me that the lesson that is being taught here has to do with the schooling of intuition. We are discovering that our intuitions, which were schooled in the physical world of everyday experience, are inadequate to the experiences of the laboratory. So there is an educational opportunity here; we are being required to change our ways of thinking.

Jane: When you read the writings of the early quantum physicists, it is clear that they found their discoveries startling. But it seems that as the mathematical formulation has become more sophisticated, people have gotten used to dealing with it at this level, and have ceased to confront the paradoxes.

Arthur: Certainly, there are ways in which we can marginalize the experience; just as we don't like to deal with death, so we put it into hospitals and hire people

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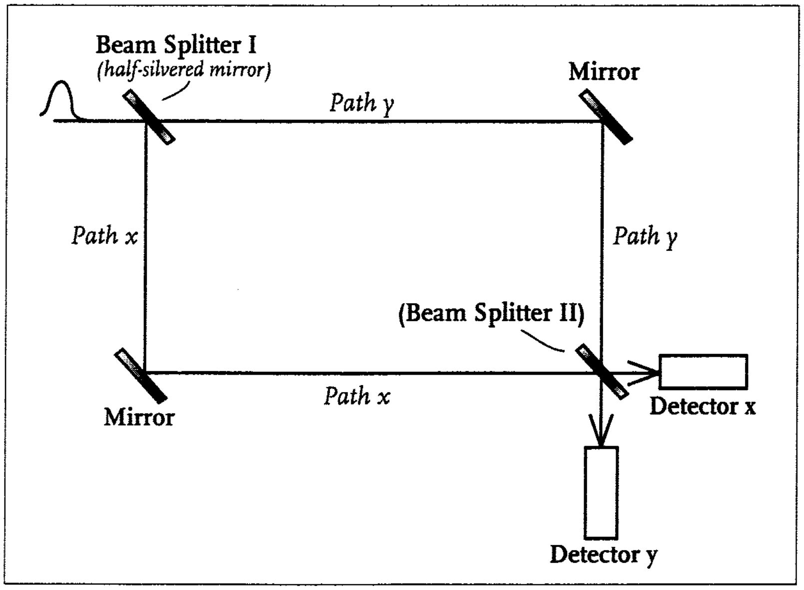
Delayed Choice Experiment



This fascinating experiment defies standard Aristotelian logic.

This experiment is based on a hypothetical "thought experiment" arising from discussion between Bohr and Einstein in the early days of quantum mechanics, and refined in 1978 by John Wheeler. In 1987, improvements in technology enabled various versions of it to actually be done, first by a team of physicists at the University of Maryland in the United States and then, independently, by a team which included Arthur Zajonc at the Max Planck Institute of Quantum Optics in Munich.

The above diagram shows the experimental set-up, which proceeds as follows, starting from the upper left-hand corner:

A single photon of light enters the apparatus (an inferometer) and reaches a half-silvered mirror, which acts as a beam splitter. If we think of the photon as a *particle*, then there is a 50% chance of its being transmitted through the mirror, and a 50% chance of its being reflected, and, as it is a single particle, it must take just one of the paths (x or y). The paths are then brought together using the mirrors and a measurement is taken, using Detectors x and y, to determine which path it has taken. It is confirmed, experimentally, that the photon takes each route 50% of the time.

If we then insert another half-silvered mirror at Beam Splitter II, we lose the information about which particular path the photon has traveled. But we obtain an effect (an interference pattern) which is compatible with the light behaving like a *wave*. In order to generate this pattern, the light would have had to have traveled along both paths x and y simultaneously—in logical contradiction to the first situation, where it traveled down only one path.

John Wheeler's suggestion was that the choice as to whether to insert the second mirror (Beam Splitter II) should be delayed until the very last instant—until well after the photon has passed through the first beam splitter. That is, if one thinks of the situation in classical terms, the photon does not know, when it comes to that first beam splitter, whether the measurement will be for a wave or a particle—whether it should take one path like a particle or whether it should take both paths like a wave. Wheeler asked: Does this make any difference to the way that the photon behaves?

The delayed choice is achieved in Zajonc's experiment by using a very fast switching device, and what transpires is that deferring the decision makes no difference to the results. The photon still behaves as if it knows "ahead of time" how it is going to be measured.

In order to account for this, both options—that it travels along one path *and* that it travels along both paths—have to be included in the conceptual framework. **That is, there is a quantum superposition state which includes both situations, and this defies standard Aristotelian logic**

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to deal with it for us. It is the same with work with the handicapped, or whatever it is that we find unpleasant about life. What I am suggesting with all these things is that we should be taking them out of the hospital and making them part of life—bringing them into the home so to speak. We should be taking quantum mechanics out of the remote corners of physics laboratories and acknowledge it as part of our world. We should grow up with it as part of our worldview.

I sometimes imagine a quantum mechanical technology which could become part of our everyday life. Take for instance these high-temperature superconductors which have been invented. There you have a quantum mechanical system which has potent technological applications. At the moment, they still need cryogenic temperatures, so they have to be located in laboratories. But what would happen if, as everyone is predicting, these become room temperature superconductors? They would be everywhere; in every refrigerator, in every motor, in everything that carries electricity, in the wires that run through your house.

The science of these superconductors is not a classical physics. So, when a repair man comes to fix your wiring, what is he going to think about what he is fixing? Is he going to be called upon, in a very natural kind of way, to think in ways that at the moment we only find in the world of theoretical physics? The same thing, I think, did happen, with the rise of what we now think of as conventional technologies. The machine, as it came to prominently feature in our landscape, changed the way we thought about ourselves and about our world. And I am wondering to myself: Will there be an opportunity for such change if quantum mechanical technologies become much more commonplace?

We are discovering that our intuitions are inadequate to the experiences of the laboratory—we are being required to change our ways of thinking.

And I would see this as an opportunity for self-transformation. It presents us with a possibility for personal growth if we realize that we are being asked to perceive the world—not just think about it, actually perceive it—differently from the way that we habitually see it.

Jane: Now, the way that you understand this matter of actually "perceiving" the world in a different way relates, I think, to your study of Goethian science, and what he called the creation of "organs of perception".

Arthur: To me, the whole matter of education has, at root, to do with the creation of organs of perception. It has not so much to do with presenting facts to the student.

We can write things down on paper, so that a person can carry them around with them—and that is important, that certain things can be written down so that they can be remembered. But everyone realizes that this is not at the heart of education, which has to do with changing a person. Now in what sense are you changing them? I would maintain that we are not just filling them up with information, but changing the way that they see the world. They may start out with a rather naive and immature way of seeing the world, but as they grow from childhood to adulthood, they gradually penetrate more and more the way it works, develop more sophisticated perceptions.

Now there are cultural determinants which bias us toward seeing the world in certain ways. The technological landscape in which most of us live, for example, tends to deny any religious or spiritual dimensions to life. This is in sharp contrast to, say, the medieval vision. The medieval world was virtually devoid of machines, full of living beings—animals and other human beings—all of whom were embedded in a gothic imagination, in which the human was held in the lap of the gods, with the angels above, etc. So in that society, there was a schooling of a particular kind of imagination, and that imagination was a concrete thing which allowed them to actually *see* these spiritual entities.

Now we have come into a modern imagination, which allows us to see things which the gothic imagination did not, and which, in its own way, is a great thing. On the other hand, it blinds us to other things, and we are resistant to change. But through quantum theory, and through many other areas—perhaps more interesting areas, more human areas—we are now being called upon to see new things. What this requires is a transformation of self, and the creation of organs of perception, which allow us to see those things. The human being is, I think, a very plastic form. Findings from research on the brain and the neurosciences show that even at the level of anatomy there is plasticity in the brain, and possibilities for re-configuration which show up at the material level.

But leaving that aside—because I think that one need not always think at the level of brain interactions—true education is a transformation—either, in the case of a

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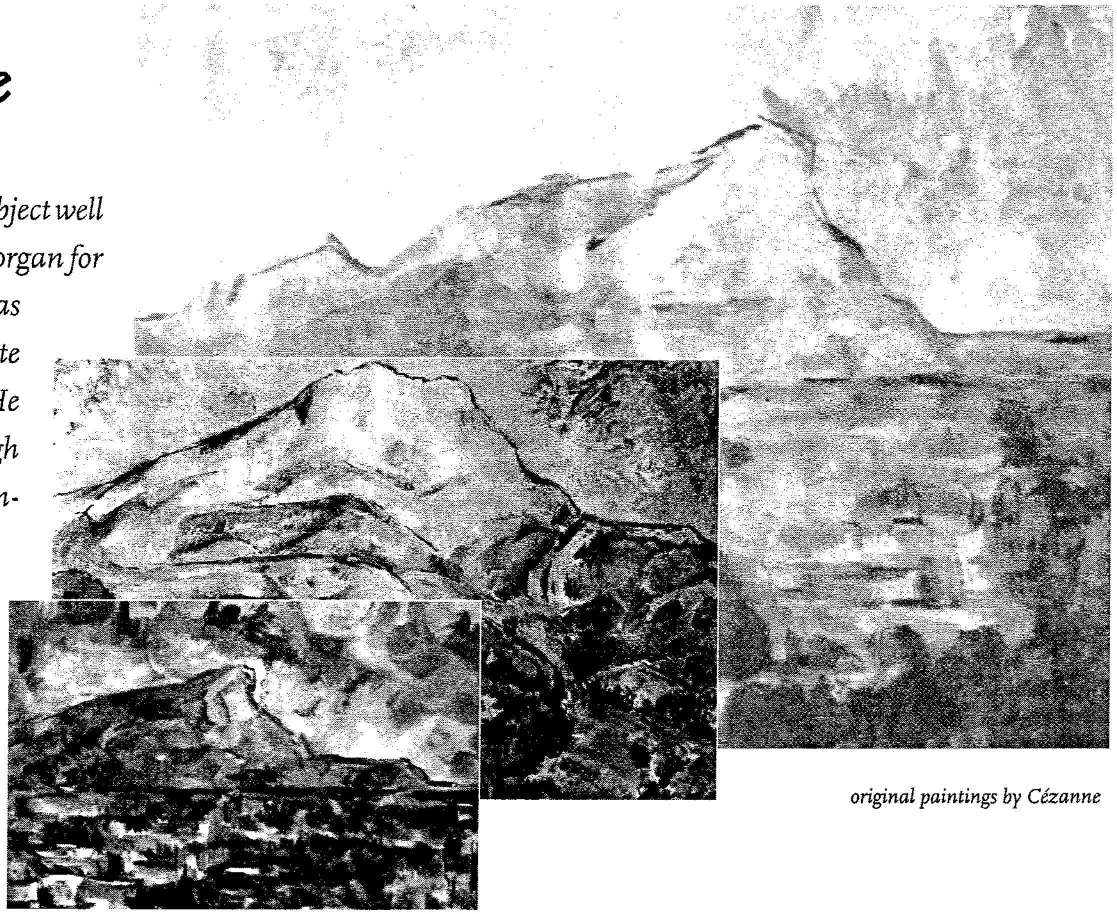
A Dialogue with Nature



original paintings by Cézanne

***Goethe** said: "Every object well contemplated creates an organ for its perception." Goethe was one of the most articulate spokesmen about this. He saw it taking place through a kind of dialogue—an interaction—with nature, with the thing that you want to understand.*

One of the great examples to my mind is the painter Cézanne. There is a story that he was standing one day with his son by a river. Cézanne was painting away; in fact, he had been painting from that exact position for the last week, painting the same object again and again and again. He remarked to his son that there was an infinite wealth of possibilities as to how he could paint this object. And he said: "What one must really do, as an artist, is make oneself concentric to nature."

Now I understand this to mean that, through one's practice, and then trying to paint what one sees, one is taking nature—who was for Cézanne the great teacher—and making oneself concentric to the being of nature. Now to me, that is formative. Cézanne recognized that what he was sculpting, what he was creating, was himself. He was using nature as the medium for that transformation, and then, having seen that, he would paint more deeply, more purely. I think Goethe was saying exactly the same thing. As an artist and as a scientist—and here I think that the arts and the sciences really have an opportunity to meet—what one is doing is "making oneself concentric to nature".

Now the creative moment, when we do this in the natural sciences, is that in which we make a discovery. There is a time when we are puzzled about something: We can't see it clearly. We study the data, we do another experiment—just as Cézanne painted his object again and again. We feel that we can't move; it gets boring. We ask, "How can this be meaningful?" What is happening here is that we aren't just gathering more and more data in some sort of dry intellectual way. We are changing ourselves so that we can come to the position of interpreting it.

—A. Z.

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child, by a teacher, or, in the case of an adult, through self-transformation.

Cézanne and Goethe are rare examples of people who were fully aware of the importance of this transformative process (see page 25). But most scientists don't pay attention to it. It is something that just happens, and it is even, very often, explained away. But actually, the moment of discovery, the moment of insight, is a wonderful one. It is the moment that all scientists really live for. I think of it as an epiphanal moment. And yet, it is a kind of mystery. One doesn't know how it happens. But it certainly comes about as a result of practice. I suppose I think of science as being, in some ways, a spiritual practice. Just as the artist, or the spiritual contemplative, are working not only on outer phenomena, but also working on themselves, so every scientist who makes a discovery has succeeded in creating a new organ of perception.

Jane: So you would say that this has always been the nature of science?

Arthur: Oh yes. One of the great examples of this was Isaac Newton when he came up with the law of universal gravitation. Newton left Cambridge in 1665 because of the plague, and went into his years of contemplation, as he called them, his "anni mirabiles"—miraculous years, which produced his greatest discoveries. And there he was under the proverbial apple tree, and what does he see which gives rise to the universal law of gravitation? He doesn't see the law written out; what he sees is an apple fall. And he said, "I saw the apple fall as the same thing as the moon going overhead."

Now that is a very strange perception. People had been seeing apples fall for millennia, and people had been watching the moon for millennia, but only he saw them as the same thing. Noone had ever seen that before. And it had come after meditating on the nature of bodily motion; on the nature of gravitation: of asking himself "What are these things?" And he had created out of those thoughts—because it has to be said, that this "object well-contemplated" does not have to be just in the outer world; it can be in the inner world, through a thoughtful engagement with the material—he had created an organ of perception. He *saw* the objects falling, and he was excited.

Now he had a problem. How would he get someone else to see this? He could get his mother out and point to the apple, and point to the moon; but she would see nothing. He could even say the words: "They are the same thing" and she would still see nothing. So it is not sufficient to have one's own epiphany for it to be also a world epiphany. To show someone else, another process has to come into it, and this is where the mathematics and such have a place. But initially it is a personal kind of knowing.

So what I am saying is that this kind of epiphany has happened at every moment of scientific discovery, from Archimedes in his bathtub; I mean, people get into the bathtub and slop around all the time, but they don't come up with a new law of nature. These realizations are also the essential nature of education. In education, one is trying to find a means—cultivate a way—by which the teacher or instructor can bring about that same moment of transformation in each of their students. I can throw a rock and I do not see, as Galileo did, a parabola. Most people don't see parabolas; they just see a rock—even baseball players who can throw things very well! To see that parabola requires an organ of perception.

I can sometimes see this transformation happen in a classroom with a group of students. Some students see something, and they light up. And other students don't get it, even though they have the same formulae in front of them. So one tries to explain it again, and again, and, gradually, they all get it. And then it is a shared epiphany; we kind of look through the corner of our eyes, and know that we have all seen the same thing. And we feel sorry for the ones who haven't seen it. For me, this is the supreme moment of education. The rest of it is of course important—the practice and the diligence, etc., but this is the real point.

Jane: So if this has been at the core of science throughout history, is there anything different about this time, now?

Arthur: Well, it seems that what is required now is that we should make this fully conscious. Also, we have a new domain of scientific experimentation with which to work. We didn't have quantum physics a hundred years ago, much less two or three hundred years ago. So what happened at the turn of the century, when people first came across the phenomenon and posed the experiments which we are now doing? They were shocked. Why? Because in thought, like Newton, they were creating forms for which there was no previous history. They saw the necessity to develop new ways of thinking which were shocking relative to the ways they were habituated to seeing it.

Now, I think that we are like Cézanne: standing by his river, painting the same thing again and again, trying to make sense of it—making ourselves "concentric to nature". That takes a certain modesty, an admission that we don't have all the answers, all the perceptions that we need. And faith that it is possible to create that new organ of perception and allow, therefore, something new to to be seen—not just thought about abstractly, but so that people can have it as a personal epiphany.

Now this is not the same as having, as we do at the moment, quantum mechanics as an algorithm—a formula that we can manipulate and use. It would be quantum mechanics as a *theory*. The word *theoria* actually means "to behold". That is the Greek root. I have just been talking to a student of the Eastern traditions, and he told me that the Tibetan and the Sanskrit roots of the word also have the same meaning—to see, to behold, not to just have some abstract theory.

Jane: If—or perhaps I should say, when—we develop this organ of perception, what kind of changes do you think it will make to the way science understands the world?

Arthur: There are a number of lessons that one can learn—and there are a number of temptations to, as it were, unlearn. One of the lessons is that they awaken us to our own irreducible place in science. It is the scientist who does science—not just in some mundane sense, but, actually, all scientific understanding, all insight, all that we mean by explanation, ultimately traces its way back to the scientist or the person who has been observing the phenomenon. It is a human activity.

And the activity has two aspects. On the one hand, there is this development of organs of perception which in turn allow us to perceive the world more deeply. The more deeply we see it, the more it works back on us again—the more organs are created. There is a constant cyclical, dialogical interchange, just as there is when two people speak. The more they talk to each another, the more the understanding between them is deepened, and there is also a change that takes place through the speaking. We can't just stand outside of the conversation, like some sort of neurophysicist or psychologist, and observe the psyche of the person opposite us. That is a really inappropriate attitude.

So we should be collaborators with nature. It is an error, a fundamental mistake, to think of ourselves just as an onlooker; a disembodied enquirer that puts questions to nature—perhaps on a slip of paper that is somehow deposited in a neutral place and then we go and get them returned with answers. It just doesn't work that way; we are always involved in the process.

One of the examples I often use with my students is optical illusions—ambiguous figures. There, something is put up, usually a black and white drawing, that can be interpreted as many things. But each of us sees it initially as one thing. The person next to us may see it in a different way. Now, they actually see it, and it has meaning. And so this shows that each person is participating in the perception; we are determining what we see, and there is no way that we can get away from it. It is one of the fundamental rules of the game.

I think that scientists should be able to accept this. They should be able to say: It's fine, this is where I belong. Then what begins to build up is a community of insight, where we all stand in front of the machine, we all have our epiphanies and also recognize that others share them. Then we become a community of enquirers—but not enquirers in the old sense of the word, but now really as collaborators with the natural processes, and with each other.

Jane: And the other aspect?

Arthur: On the other hand, we tend to want to replace the perception with a hypothetical construction. We see the apple falling and the moon going overhead as the same thing. That becomes the law of universal gravitation, which is an abstract equation which I write down. If I give that to a student, then it defines the extent of their involvement, and they don't ever get to see the apple fall.

It presents us with an opportunity for personal growth, for transformation, if we realize that we are being asked to perceive the world—not just think about it, actually perceive it—differently from the way that we habitually see it.

Now seeing the apple falling, like seeing the moon overhead, carries with it a meaning which is much larger than any formula. It is perceptual—there is a whole kind of gestalt which it has, a whole form, a whole gesture, which is just as much a part of that experience as the final formula. If I leave it at the level of an equation, it is as if I have gone to a medicinal plant and extracted from it the essential ingredient. Working like that may be adequate if your aim is, for instance, to send ballistic weapons over the other side of the world. But it may be inadequate for other things—in particular, if I am interested in a science which is sensitive to ethical dimensions, moral issues. Because what I have done is factored all those things out and disposed of the moral dimensions, and kept only this dry, objective (so-called objective) mathematical element.

What I am suggesting is that we recognize that the observer's place is really at the center of the laboratory;

that the epiphany is the essential moment, and that the abstraction from the epiphany to the equation is a kind of de-naturing of nature. Then we can still use equations, but when we do we should be conscious of the fact that we may have stripped away some really important things. And if we want, we can then re-integrate our knowledge. Then the knowledge is not dismembered, with its most human aspects discarded and reduced to bare bones. But rather, as Goethe wanted to have it, the phenomena themselves become the theory.

This means that *I* have to become active, because the phenomena only have meaning if I am there. Then *theoria*, as beholding, takes on the full meaning, and has the full richness of the moral and spiritual dimensions which I think the world really needs. And this can open things up in other directions—directions which point to my full humanity and humanity around me, as well as the significance of the Earth as more than a mineral resource.

Jane: Can we talk a little about the underlying change in our concepts which all this would seem to imply? It has been said that we in the Western world have developed a culture based upon separateness, and that we are now moving toward another mode which emphasizes unity, and wholeness.

Arthur: I think that many of us are keen to see the emergence of a science which emphasizes union rather than separation. But I also think that there are some dangers in saying this. One can reduce things to dismembered entities, to fragments ad infinitum, to the point where everything falls apart. But one can also reduce things to the kind of unity where everything disappears. So I think that what we are looking for is not just a kind of soup, where everything disappears, nor some arid wasteland where everything is dried out and separate from one another, but for a balance—a compromise—where we can participate in both modalities.

This is not a static balance. My image of it is a situation in which we can fully participate in both modalities, because that which participates in, and which activates these different modalities of seeing—that is, the human being—is actually transcendent to either of them. The person who is enquiring can turn his or her head and see wholes, or they can turn their head and see parts. Nature responds, as C. S. Lewis once said, only to those questions that we put to her. If we put questions that are born of a fragmented consciousness, we are only going to get answers which depict a fragmented world. If, on the other hand, we put questions which draw her out as regards the wholeness of nature, we are going to find truths—and they are truths, not illusions—which depict that wholeness, and those kinds of interrelationships.

Jane Clark is Editor of Beshara Magazine, *Oxford, UK.*

In quantum mechanics, in the experiments I have been describing, we have one example where there are elements which are open to an interpretation of wholeness. That is interesting, in itself, on one level. But it also points to a much larger kind of integration. Simply to show that two electrons with spins anti-parallel can enter into a superposition state which gives us an interesting result, as far as the EPR experiment goes, is one thing. We can still continue to treat this in a very abstract, algorithmic, mundane way. To see the whole, we have to take another step, to another level of wholeness, which is to integrate the observer back into nature.

Now that is not required in order to do the mathematics, but I think that it is required in order to understand the things we have been talking about—the process of scientific discovery; the process of insight, what it means to explain as a consequence. And this also connects with the image of wholeness, that what we do in order to gain insight is to penetrate into nature. The aim is to become part of it, to participate in it.

I think sometimes that instead of a sort of transcendental realism—where the world stands out beyond us, where the atoms and so on cannot really be experienced—what we really have is a participatory universe; a "participatory realism", in which we are completely insinuated . And the acceptance of this is required for any kind of discovery—not only scientifically, but about each other in the everyday world. Because it implies that mode of sympathy that allows participation in the world of the other.

Jane: So you think that what is happening in science now is just an aspect of a much larger social change?

Arthur: I think it's very important to emphasize this larger cultural change; that it is not being driven by new discoveries in quantum mechanics, but vice versa; the phenomenon of coherent superposition stands as a kind of metaphor—a kind of symptom—of a larger kind of participation, which I think is really needed in our times. And it is not just the scientists who are affected; it is the people who are working in organic agriculture, in new forms of education, in new forms of healing, in self-development and the contemplative sciences.

And how we deal with this change—whether we deal with it consciously or whether we deny and refuse to listen to its demands, can be very important. By attending to it, by working with it, and being conscious and clear about it , one can, I think, be led much further than if one is reactionary and difficult. □