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#12

Dear Readers,

You might say that this issue of *In Context* is about great questions and fundamental mysteries. In the introductory article, for example, the question arises whether there is a rock-bottom, minuscule scale of subatomic events from which all scientific explanation proceeds. And, in slightly different terms, is the world best understood as built up from basic, infinitesimal building blocks, or does such a view seriously compromise our ability to appreciate and understand the phenomena we are given to investigate? Why has the building-block view of the universe gained such a powerful hold upon our minds?

Then there is the first feature article, which asks: What lends bacteria their amazing powers of adaptation? Do these powers arise purely and simply from alterations and rearrangements of genes as "master controllers" of the organism, or does the organism within its larger context shape and control the genes fully as much as the genes shape and control the organism? The evident answer provided by the bacteria runs counter to our society's prevailing fantasies about the promise of genetic manipulation.

And again: Who is the giraffe? Or, perhaps less objectionably for some, What recognizable and governing unity comes to expression in the giraffe—for example, in its extraordinary tendency toward the vertical, in its weightless, floating gallop across the African plain, in its strong vision and diminished sense of smell, and in its social aloofness? The reader who pursues this question seriously may also be led to ask, What does the recognizable unity of this remarkable creature tell us about a mainstream science that acknowledges no compelling unity of any organism, but only a collection of mechanisms?

Lastly, if there is an unavoidably mysterious domain in modern science, surely it is quantum physics. In the popular mind this discipline stands for little more than insoluble paradox. But, as the concluding article in this issue illustrates, the sense of wonder and mystery remains vivid still today for some of the world's leading physicists. Many believe that figuring out the puzzles of quantum physics will at the same time be to discover the contours of a transformed science.

Discovering the contours of a transformed science is, of course, the core mission of The Nature Institute. We hope the questions and explorations in this issue will stimulate your own reconsideration of the scientific ways of knowing that have for so long come to dominate the great cognitive enterprises of our society.

Craig Holdrege Steve Talbott

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The Nature Institute

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The Building-Block Universe

Steve Talbott

IN HIS ESSAY ON "Newtonianism, Reductionism, and the Art of Congressional Testimony," physicist Steven Weinberg (2001) tries to get a grip on why "we all do have a sense that there are different levels of fundamentalness"—why, for example, DNA is "fundamental to biology," and particle physics is "fundamental to everything." In science, he says, "we try to discover generalizations about nature," and these, it turns out, give us a sense of direction because "some generalizations are 'explained' by others." After all, "does anyone doubt that real materials exhibit [higher-level] phenomena because of the properties of the particles of which the materials are composed?" So it is that

> There are arrows of scientific explanation, which thread through the space of all scientific generalizations .... These arrows seem to converge to a common source! Start anywhere in science and, like an unpleasant child, keep asking "Why?" You will eventually get down to the level of the very small.

> And further:

> no biologist today would be content with an axiom about biological behavior that could not be imagined to have an explanation at a more fundamental level. That more fundamental level would have to be the level of physics and chemistry, and the contingency that the earth is billions of years old. In this sense, we are all reductionists today.

Weinberg not only finds the arrows of explanation in nature consistently pointing downward; he also suspects we may be close to the "final source" of explanation. For as we study smaller and smaller structures, the physical principles we discover become simpler and simpler. They become increasingly coherent and universal, reflecting "something that is built into the logical structure of the universe at a very deep level."

Building Blocks Without Substance

The attempt to find ultimate explanation at "the level of the very small" leads naturally to a building-block view of the world. If the small things are fundamental, then the secondary, bigger things must result from their aggregation. The world, we can imagine, is built up from parts, rather as we construct the various objects and mechanisms of modern life from their constituent parts. There is no over-estimating the compelling force of this view upon the modern mind. As physicist David Bohm remarks,

> When it comes to the informal language and mode of thought in physics, which infuses the imagination and provokes the sense of what is real and substantial, most physicists still speak and think, with an utter conviction of truth, in terms of the traditional atomistic notion that the universe is constituted of elementary particles which are "basic building blocks" out of which everything is made. (Bohm 1980, pp. 14-15)

The strange thing about the bottom-up, building-block universe is that it receives no support whatever from science itself. As another physicist, Nick Herbert, puts it: "the unremarkable and common-sense view that ordinary objects are themselves made of objects is actually the blackest heresy of establishment physics" (1985, p. 22). Herbert is here acknowledging how physicists have brought no end of trouble upon themselves by imagining their smallest entities to be like the things of ordinary experience—for example, waves and particles. Their "building blocks" have dissolved into probabilities and abstruse mathematical formulas with no thing-like reference at all.

Actually, we see something like the reverse of the building-block model. The interference pattern (along with the entire experimental set-up) in the famous double-slit experiment explains the behavior of the presumed individual photon at least as much as the photon explains the pattern. (See "Quantum Puzzles" in this issue.)

The building-block universe is a holdover from 19th-century science. If it has a death-grip upon our imaginations, this is at least in part due to inadequate notions of scientific explanation. Weinberg speaks of a search for generalizations where "some generalizations are 'explained' by others" and eventually, as with an "unpleasant child," our why-questions lead us down to the very small. But this downward spiral is wholly dependent upon the kinds of questions we ask and the kinds of answers we are willing to hear.

If our entire method is one of *analysis*, so that we would explain every whole by looking downward, dissecting, logically distinguishing—if, like the child, we know only how to pull things apart—then obviously we will be led to smaller and smaller pieces. But, at the same time, we will be left with a problem: how do we say anything meaningful about a world we never consider in its own, unfractured terms? How do we avoid an endless regress of explanation, where each thing we cite is in turn "explained" by other things lower down, none of which we can ever stop and experience for what it is? Which also means: we can never stop and *say* what it is.

Generalizing Toward Emptiness

Nature herself suggests a need for much more than downward-directed analysis alone. Do organisms explain their environment, or does the environment explain the organisms (Holdrege 2000)? Does the stream explain its local meanders and eddies, or do the latter explain the stream (Bohm 1980, p. 10)? It always works both ways. We never find in any meaningful context—which is to say, in any meaningful whole—that the chain of cause and effect works only in one direction. Even with a machine it makes no sense to say that cause and explanation flow upward from the smallest parts. Our intellects may need to focus successively on isolated parts as we work toward an understanding of the whole, but we should not mistake our own needs for the working of the machine.

What misleads someone like Weinberg is the fact that we do discover a kind of syntactic structure or lawful regularity in the world's phenomena, and this structure can be traced downward into the very small. The entire analytical thrust of science has aimed at this downward tracing. But this is where the great confusion occurs. For while there is no sphere of human or natural activity that does not exhibit syntactic structure and lawful regularity in the relations of its parts, this lawfulness *never* explains the actual course of events taken as a whole (Talbott 2004). Rather, it characterizes only certain abstract aspects of events.

Consider for a moment the analysis of one particular phenomenon—human language. We can indeed abstract lawful regularity from all language. For example, we can obtain a grammatical or logical syntax, and this in turn can lead us to the notion of grammatical or logical atoms as basic building blocks of speech. Without such a regular and more or less predictable, particulate structure, we could not speak meaningfully. Yes, there is a grammatical and logical structure implicit, for example, in Martin Luther King's "I Have a Dream" speech. But once you have gone as far as possible in abstracting such a formal structure, you could never, by looking at the empty structure alone, find your way back to the actual content of the speech. (Imagine looking at a page of logical symbols and wondering what they might be *about.*) But you *can* find your way from the content to the abstraction. This is hardly surprising, since any content explains what is abstracted from it in a much fuller sense than the abstraction explains the content.

It is, in the end, self-evident: in every sphere where we find law, we also recognize that whatever is capable of "obeying" this law must have a substance and character that is more than the law it obeys. This substance and character is exactly what the prevailing scientific method simply refuses to look at. As Weinberg points out, the scientist seeks laws that are *generalizations*. We generalize by looking only at what things have in common—just as we seek a law of gravity that applies equally to moon and apple, fish and rock. We can find such a law, but we do so by ignoring everything that makes the fish a fish and not a rock. By abstracting from things only what they have in common, and by moving downward toward ever more universal generalizations of the sort Weinberg celebrates, we eventually arrive at those "simple" and "coherent" statements that apply to almost everything and therefore tell us almost nothing about any actual content of the world. This, of course, is no problem if we have already managed to develop a disinterest in all meaningful content.

There is another way to seek law in the world. That will be the subject of the next article in this space. Meanwhile, please note that the topics addressed here are dealt with at much greater length in a collection of essays on our new website. You will find them at http://qual.natureinstitute.org. See in particular "The Reduction Complex."

References

Bohm, David (1980). *Wholeness and the Implicate Order.* London: Routledge and Kegan Paul.

Herbert, Nick (1985). *Quantum Reality: Beyond the New Physics.* New York: Doubleday.

Holdrege, Craig (2000). "Where Do Organisms End?" *In Context* #3 (Spring). Available at http://natureinstitute.org/pub/ic/ic3/org_and_env.htm.

Talbott, Steve (2004). "Do Physical Laws Make Things Happen?" *NetFuture* #155 (March 16). Available at http://qual.natureinstitute.org.

Weinberg, Steven (2001). *Facing Up: Science and Its Cultural Adversaries.* Cambridge MA: Harvard University Press.

Visit Our New Website!

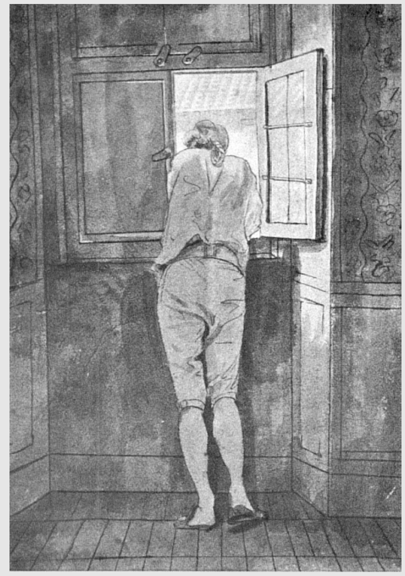
Late August saw the inauguration of our radically upgraded website, http://natureinstitute.org. Not only is the site greatly improved in visual presentation and navigation, but we have added a good deal of new content. In addition to pages devoted to educational programs, public events, and resources, we have the following centers focused on research content:

Seeing Nature Whole: A Goethean Approach. Many of us were introduced to biology—the science of life—by dissecting frogs, and we never learned anything about living frogs in nature. Modern biology has increasingly moved out of nature and into the laboratory, driven by a desire to find an underlying mechanistic basis of life. Despite all its success, this approach is one-sided and urgently calls for a counterbalancing movement toward nature. The articles and background information collected here help to provide this new, healthier approach.

Genetics and Biotechnology. The Nature Institute's contextual, qualitative approach to the study of organisms and heredity reveals the broader story of an organism, its interplay with the environment, and its relation to human society, vividly illustrating the limitations and dangers of single-target biotech solutions to complex problems. The question how humanity can obtain nourishment and healing substances from the earth without damaging the web of life that sustains us is critical. Genetically engineered plants and animals are technology's newest answer to solving the world's food and health problems. From soybeans that are resistant to herbicides to corn that produces its own pesticides, we are surrounded by a whole new realm of manipulative power.

This technology, which aims to effect discrete and predictable changes, overlooks the fact that organisms are living, complex systems, interacting with changing and dynamic environments. Any change to a part affects the whole. For this reason genetic manipulation is inherently unpredictable. When driven by the desire to control, gain scientific fame, and reap large profits, this technology presents an imminent danger to the interconnected and interdependent array of organisms and forces that serve as the context for all life on earth.

Technology and Human Responsibility. When science is governed by a conviction that the world is a machine, the distinction between science and technology naturally grows tenuous. Indeed, the influential philosopher, Daniel Dennett, has argued even of biology that it "is not just like engineering; it is engineering. It is the study of functional mechanisms, their design, construction, and operation." And the University of Texas historian of science and technology, David Channell, argues that we should no longer think of technology as applied science; rather, "science is just applied technology."



Goethe looking out his hotel window in Rome in October, 1876, during his life-changing "Italian Journey." Watercolor by J.H.W. Tischbein. To learn how Goethe (and Rudolf Steiner, Owen Barfield, and Kurt Goldstein) inspire the work of the Institute, go to the "About Us" page on our new website and follow the links.

The study of technology is therefore essential to an understanding of what science is becoming today. You might say that all the work of The Nature Institute relates to technology—that is, we are concerned to rise from a technological or mechanistic view of the world to a living, qualitative, and contextual understanding of it. In order to achieve this, we must understand the character of technological thinking as deeply as possible, and learn how to transform it.

Evolution. Research into the holistic nature of organisms has large implications for the way we think about evolution. By appealing to mutation and natural selection, Darwinian evolutionary theory tends to "explain" (construct evolutionary stories about) the evolution of adaptive characteristics in isolation from the rest of the organism. One conceptually abstracts, say, horns or grinding teeth from the whole organism and interprets each as its own kind of "survival strategy." A more adequate understanding of evolution requires that we first investigate the organism as a whole and how its members interrelate and interact within the context of the whole organism and its environment. This holistic understanding can then form the starting point for thinking about the evolution of the animal. The evolutionary biologist Dobzhansky's famous statement that "nothing in biology can be understood except in light of evolution" is a grand claim that we believe is, in the end, true. But we have a lot of work to do before we arrive at this understanding.

Science Education. We believe that science education is all about helping students to develop their capacities of observation and thinking as tools for understanding and participating in the world. It is not primarily about conveying a body of past knowledge.

Since much science today is theory-driven, students often end up taking theories for the phenomena themselves. In the worst case, science becomes a theoretical edifice that one adheres to and everything is subsumed within its categories. It becomes a kind of world unto itself. Science education needs to begin with immersion in the phenomenal world and out of this immersion questions arise that guide further inquiry. Science education should be discovery-based and open-ended. In this approach, nature is the expert, the teacher is the guide and students are the apprentices helped by the guide to learn from the expert. The knowledge that arises is not knowledge disconnected from human experience; rather, it enhances our ability to understand the world we live in.

....

In addition to these centers, you will find a bookstore, as well as search facilities. We consider the site just a beginning, and hope to continue adding substance to it over the coming months and years. We will be aided in this by your critical comments and suggestions, which you may send to info@natureinstitute.org.

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Beyond Reductionism

A developing collection of papers on our website runs under the title, "From Mechanism to a Science of Qualities." These are part of an effort by Steve to (1) articulate a fundamental critique of the dominant, quantitative science—one that fully acknowledges the strengths of this science; (2) explore the path toward a new, qualitative science; and (3) lay hold of the underlying epistemological issues with which any science must reckon.

The four central papers currently available (there are various supporting papers as well) fall into the first category above. These are "The Vanishing World-Machine," "The Limits of Predictability," "Do Physical laws Make Things Happen?" and "The Reduction Complex." This last essay summarizes some of the difficulties with the reigning materialism, mechanism, and reductionism, which offer us these results:

* Materialism without any recognizable material.

* Mechanism that ignores actual machines, occupying itself instead with the determinate and immaterial clarity of machine algorithms.

* Reductionism that reduces reality toward precisely formulated contentlessness.

* A one-sided method of analysis that never stops to tell us about anything in its own terms, but forever diverts our attention to something else.

* A refusal to reckon with qualities despite the fact that we have no shred of a world to talk about or understand except by grace of qualities.

* Cause wrenched apart from effect; all becoming—that is, all active be-ing—frozen into stasis.

* Bottom-up explanation that tries to explain a fuller reality by means of a more impoverished reality, ignores the bi-directional flow of causation between all contexts, and naïvely takes the smallest parts of the world-mechanism as most fundamental for explaining it.

* Finally, a denial of mind as an irreducible and fundamental aspect of the universe—this while scientists increasingly describe the world as driven by, and consisting essentially of, little more than collections of mental abstractions—mathematical formulae, rules, information, and algorithms.

This entire body of dogma, Steve suggests, has for some time been slowly collapsing in upon its own absurdities. It is not so much that particular discoveries disprove the reductionist position as that—much like during the earlier break with medieval thought—more and more people simply find it impossible to look upon the world in the old way. It is nevertheless important to characterize as precisely as possible the inadequacies of the old view in order to move healthily toward a new science that does not sacrifice the virtues of the old—and in order to avoid allowing old, limiting habits of thought to reassert themselves under new guises.

Steve would love to hear your response to these papers. Send it to stevet@natureinstitute.org.

A Budding Research Community

For the second time, we held a week-long advanced summer course in Goethean science for people who had already attended previous courses. Nine individuals participated, along with Craig and Henrike. Since everyone had some familiarity with a Goethean phenomenological approach to science, we worked together on deepening this understanding. We studied the composite (daisy) family, observing and comparing the ox-eye daisy, wild chicory, daisy fleabane, and yarrow. We attempted to grasp some of the unifying qualities of this remarkable family—a family that intensifies the principle of flowering to such a degree that the various species create unified "super-flowers" (flowerheads) out of the many individual flowers.

This year we incorporated individual work and presentations into the course. During the afternoons each participant chose a topic to focus on for the week, such as studying the landscape and habitat features of our wetland or studying and drawing a particular white oak. In addition, a number of individuals had been working on their own projects during the year and reported on their research. These presentations were especially memorable, since each person in her own way showed the fruitfulness—and the trials—of the new, Goethean way of thinking and observing. Here is a glimpse into these ongoing studies:

** Christina Root, an English professor, gave a presentation on the importance of language for the Goethean approach to science. She showed how Thoreau worked in a Goethean spirit, illustrating through passages from his work how he was able to portray subtle and essential features of nature through his original and eminently vivid language.

** Catherine Read has been working with Craig for the past few years and has an interest in peat fibers. This took her on a path to explore bogs, which are a habitat in which peat develops. She described her visits to bogs and gave a careful presentation of her methodical approach to gaining a more living picture of their qualities, describing the way she observed, built up inner images, drew from memory what she observed, and then returned to observe at other times and under different conditions during the year. On this path an ever clearer picture of the bog as a kind of "habitat organism" emerges.

** Bet Dews discussed her research on the human liver. She was interested in how to apply Goethean methodology to an internal organ. This is no small challenge, yet an extremely important task for every teacher. Bet will be teaching 10th graders about human physiology this year. She led us through the complexity and diversity of liver functions to a picture of the central place this steady, yet flexible and almost fluid organ holds as a transformer of substances.

** Ann Kleinschmidt shared with us her efforts to relate whole-organism studies to her work with proteins as a molecular biologist. She observed the leaf metamorphosis in members of the Brassica (mustard) family during the year and some of her students carried out protein analysis from different species and from different leaves (lower, middle and upper) on the plants. It was clear that the plant produces the proteins (called peroxidases) in different forms and different amounts in a highly context-dependent way. This exciting project, which tries to bridge the usually vast chasm between molecular and morphological studies, is still in its beginnings. Ann is on sabbatical from Allegheny College this fall and will come to the Institute to work further with Craig on the project.

This course has become a focus for people interested in seriously pursuing a Goethean phenomenological approach. We see it as central to the Institute's mission to provide a forum and stimulus for the further development of this approach and look forward to doing more in this direction.

Participants in the 2004 advanced summer course observing and comparing yarrow and the ox-eye daisy.

Reading the Gestures of Life

Fifteen participants, coming from as far away as Georgia and Hawaii and from as near as a couple of miles from the Institute, participated in this year's "Reading the Gestures of Life" summer course. The course had three components: projective geometry to begin the day, then plant study and Goethean methodology, and finally drawing (in black and white and with pastels) in the afternoon. Each day concluded with a review and open discussion forum. Here are some comments from the participants' course evaluations:

"The beauty of this intensive is the weaving together of ideas from all three [activities] and the complementing effects." "I felt the course was indeed an organic whole. Each part, so different, nevertheless fed into the other, balancing, encircling and complementing each other. I came away each day knowing my mind had been stretched and opened, my perceptions deepened and sharpened, my soul enriched and fed."

"I didn't have any concrete ideas about what [the course] was going to be like. I am almost 'blown away' by how integrated and inspiring and stimulating a week it has been, in a very low-key but concentrated way."

"[Geometry] was a real treat. The exercises were explained so well, neither too much nor too little, so that discovery was maximized."

"I found the [plant study] completely engaging - going back and forth from the whole to the parts, being reminded not to add what's not observed, not to get too comfortable or assume what is, was, will happen. Discussions were stimulating and well guided."

"The presentations of artistic techniques [in the drawing sessions] were so lucid and helpful that for the first time in my life I felt I could begin to understand how to move in an artistic medium, and that maybe, after all, I do have some small artistic spark."

"I realize how quickly I move through situations, making assumptions, jumping to conclusions. This course has provided a way to begin to hold back on making conclusions—about a thought, a situation, a person."

The Institute's south-facing porch, covered with a lovely concord grape vine, lends itself well to the drawing sessions.

Down in the wetland participants take a closer look at the fruit of a skunk cabbage.

Does the Brain Think and Act?

Neuroscientists fully recognize, according to Siegward Elsas, that the so-called centers in the brain are effects at least as much as they are causes. These centers result from, and are shaped by, the activity of the developing child. But as the brain structures take on form, we can use them as tracks to carry on further thinking.

Despite the general recognition of this truth, the brain is widely thought of as the producer of thought, pure and simple, and as a command center accounting for bodily movement. The Nature Institute's research staff, along with medical student Cathy Sims-O'Neil, recently spent a day with Siegward, who led us through a critical assessment of these common assumptions. A medical doctor engaged in research, Siegward is currently Assistant Professor of Neurology at Oregon Health and Science University. He has for many years concerned himself with the role of the nervous system in human consciousness and free will.

In our meeting together, Siegward reviewed various indications that, in contrast to the other, active bodily organs, the function of the nervous system is a passive one. Like a mirror,

> it reflects in its activity everything else that is going on around it. In neurophysiological terms this is referred to as "representation." The electrical activity of the nervous system, more precisely its time structure in many frequencies, reflects how and where we touch something with our skin, it reflects what we see and hear around us, it reflects the activity of our inner organs via the autonomic nerves, and it even reflects our intentions to move and what we feel and think.

This, Siegward went on to note, might lead some to think that the nervous system "does have an active function of its own, namely in producing our inner experiences, or mental images, as well as our outer movements, similar to how the liver produces proteins for the blood and excretes bile." But to test this view, we need to explore, not only whether the electrical activity of the nervous system is *necessary* for our inner experience and bodily movement, but also whether by itself it is *sufficient* to produce these.

The necessity can hardly be doubted, but there turns out to be considerable evidence for the insufficiency of nervous activity to explain thinking and movement. While experimental electrical stimulation of muscles, nerves and brain can produce various bodily motions or feelings or thoughts, these are always pathological in one way or another. For example, they are often explicitly experienced as involuntary, and at the same time they may prevent normal, voluntary functioning. They also tend to be disconnected from all meaningful context.

Siegward presented many other aspects of perception and nervous system performance. His general conclusion—or, rather, the hypothesis he is pursuing—is that the brain no more produces our thoughts and intentions than it does the light of vision or the strength of our movement. Rather, the thinking and sensory processes "leave an imprint or reflection in the brain. If the corresponding part of the brain becomes damaged or lost, we become incapable of forming the particular kind of mental image which is associated with that part of the brain—just as we lose the capacity to see when we lose an eye."

We at the Institute hope to have further opportunity to pursue these issues together with Siegward.

Trackers Jonathan Talbott (pointing) and Michael Pewtherer (right) led groups in the winter and spring on Saturday wildlife tracking workshops. Participants learned to see the landscape with new eyes, where not only tracks in the snow or mud, but also markings on a tree or the way a limb breaks, become signs of the activities and lives of diverse animals. Watch for upcoming winter tracking.

Thank You!

Our enthusiastic thanks to all of you who have contributed money, services, or goods to The Nature Institute (or to its online publication, *NetFuture*) between March, 2004, and the end of September, 2004.

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Genes Are Not Immune to Context

Examples from Bacteria

Craig Holdrege

One of the most widespread misconceptions concerning the nature of genes is that they have a defined and fixed function that allows them to operate the same in all organisms and environments. We have the picture of the robust gene determining all the characteristics an organism has. And this gene will do the same thing in a bacterium as in a corn plant or human being. It doesn't care where it is. The gene carries its set of instructions with it wherever it goes and strictly carries out its duty.

This picture informs genetic engineering. Take a gene from bacteria and put it into a plant and the plant will produce its own pesticide or become resistant to a herbicide. Since such transgenic plants exist, the proof is evidently in the pudding. Genetic manipulation works; genes are faithful workhorses. But does genetic manipulation work the way we imagine with our schematic pictures? What else may be occurring that doesn't fit into a neat mechanistic scheme?

It's somewhat ironic that precisely within the last ten to fifteen years—the period in which genetically modified crops have been developed and commercialized in the U.S. and some other countries—a wealth of research on genes in relation to environmental effects has been carried out, showing that genes are anything but automatic instruction programs immune to their context. This research has significant implications for the way we assess genetic engineering. Unfortunately, it often seems that the results of this basic research have little effect on the minds and pocket books supporting the global drive to manipulate organisms genetically. In this article I'll discuss some examples of the contextual gene in bacteria.

The Interactive Gene

With the widespread use of antibiotics in our culture, many bacteria have become resistant. They thrive even when subjected to high doses of antibiotics. As a rule, the resistance comes at a cost, since the resistant bacteria tend to grow slowly. But when they are grown in laboratory cultures, some of these resistant bacteria will experience so-called compensatory mutations—they stay resistant, but change genetically in a way that allows them to grow fast like wild, nonresistant strains. Others mutate back to the wild form and lose their resistance altogether.

The question arises whether such mutations (changes in genes or in higher-order genetic structures) are in any way dependent on the environment. The traditional view, rooted deeply in the Neodarwinian theory of evolution, holds that genes mutate spontaneously and independently of the environment. The classical experiment with bacteria by Luria and Delbrück in the 1940s gave clear evidence that such spontaneous, milieu independent mutations exist (Luria and Delbrück 1943). For decades this experiment (along with other evidence) served as the rock solid "proof" that genetic mutations, except for extreme cases involving irradiation or exposure to chemical toxins, are not influenced by their environment. But more recent research shows that mutations do in fact arise in response to changing environmental conditions.

A group of biologists in Sweden investigated whether the above-mentioned compensatory mutations and the reversion to the wild form in bacteria are influenced by the environment (Björkman et al. 2000). They grew antibiotic-resistant bacteria—in the absence of antibiotics—as laboratory cultures (in petri dishes) and also inoculated mice with the same bacteria. The researchers monitored the mutations that occurred in the bacteria in these two different habitats. They found that compensatory mutations occurred in both habitats, but, to their surprise, they discovered that the way the genetic material changed differed significantly depending upon the environment. In the case of streptomycin-resistant bacteria in mice, they found ten cases of identical compensatory mutations *within* the resistance gene. In contrast, this gene never mutated in the lab-cultured bacteria, where they found fourteen compensatory mutations in genes *outside* the resistance gene. Evidently, the environment had everything to do with what kind of mutations occurred. "Mice are not furry petri dishes," as the title of a commentary article put it (Bull and Levin 2000).

The authors conclude that the mutations are “condition-dependent” and suggest that some unknown “mutational mechanism” limited the mutations in the mice to a specific part of the resistance gene while also increasing its mutation rate. Whatever the details of cell physiology turn out to be, it is clear that the genome of the bacteria changes in relation to a specific kind of environment. The bacteria—down into their genes—interact with and evolve in relation to their environment.

Adaptive Mutations

In another recent study (Bjedov et al. 2003), a research group in France gathered wild strains of the bacterium *E. coli* from a wide variety of environments—the large intestines of humans and different animals, soil, air, and water. In the end they collected 787 different strains. These strains were given optimal conditions in lab cultures and began to grow and multiply rapidly, mimicking ideal conditions in nature where bacteria reproduce quickly. But in nature, bacteria are also exposed to times of dearth, where the substrate they live upon, for example, is suddenly used up. To mimic these conditions, the researchers withheld nutrients for a seven-day period. Most bacteria survive under these conditions, but they no longer grow and divide.

The scientists measured the rate of mutations occurring in the cultures the first day after withholding nutrients and then again at the end of the seven-day period. During this time the mutation rate increased on average sevenfold. In other words, the mutation rate increased dramatically when the bacteria no longer received adequate nutrition. The bacteria switch, in the words of the authors, “between high and low mutation rates depending on environmental conditions” (p. 1409).

Such a stress-induced increase in mutation rate has been discovered in many laboratory strains of bacteria. Does this increase in mutation rate serve the bacteria, or is it a kind of last gasp, a dissolution of the bacteria before they die of starvation? The answer is clear: the bacteria produce unique kinds of mutations during such periods of physiological stress, some of which help the bacteria survive under specifically those conditions. One speaks of “adaptive mutations.” (See Wirz 1998 and Rosenberg 2001 for good overviews of the research and literature.)

For example, there are strains of *E. coli* that have lost the capacity to utilize the sugar lactose as a source of energy. If such a strain is cultured in a starvation medium with lactose as the only energy source, most of the bacteria remain in a stationary phase until they die. But under these conditions some of the bacteria begin to hypermutate, which means they rapidly create a large number of mutations and among these are ones that allow them to live from lactose. The bacteria with this ability survive, multiply and form new colonies. In at least some cases such adaptive mutations arise only in the specific medium—that is, the mutations allowing bacteria to utilize lactose don’t occur when bacteria are grown in a medium with sugars other than lactose.

In other instances, *E. coli* bacteria do not hypermutate, but find another way to deal with the environmental challenge. Some of the bacteria in the medium with lactose produce multiple copies of the gene related to their inability to live from lactose. This gene amplification seems at first absurd. But scientists found that *E. coli* strains unable to grow when they only receive lactose as a nutrient do form enzymes that break down lactose, but in inadequate amounts. When the bacteria amplify the defective lactose enzyme gene, the cumulative effect is that they produce enough enzymes to break down a sufficient amount of lactose to grow slowly and survive – a remarkably active and meaningful genetic adaptation. This amplification occurs in no other genes in the bacteria. It is specific to the lactose enzyme gene and clearly induced by the environment.

Transfer of Resistance

Bacteria have a further way of adapting to new conditions. I have already mentioned antibiotic-resistant bacteria. Cholera bacteria, for example, are normally susceptible to different antibiotics. After 1993 antibiotic-resistant cholera bacteria rapidly spread around the globe. How could this occur? Scientists discovered that these bacteria are simultaneously resistant to at least five different antibiotics. They found that the genes related to this resistance were all grouped together and formed a “packet” of genes that can move from bacterium to bacterium.

A research group at Tufts University in Boston recently discovered conditions that facilitate this movement and uptake of genes (Beaber et al. 2004). When bacteria are grown in cultures with concentrations of antibiotics that are not sufficient to kill them, they go through physiological changes similar to what happens to bacteria in a starvation medium. Part of this transformation is called an SOS response. It comes about when DNA is damaged and involves DNA repair and duplication. The Tufts scientists found that during the SOS response the bacteria also increased the transfer of the resistance gene clusters to other bacteria. Evidently, the use of antibiotics promotes the spread of antibiotic resistance among bacteria. In this way, once resistance is anchored in mobile genetic elements, it can spread rapidly. *(continued on page 23)*

The Giraffe in Its World

Craig Holdrege

In standard evolutionary thought, the giraffe tends to be explained in terms of a "long-necked survival strategy." In In Context #10, *I described the shortcomings of this view. Now, in the following, I begin painting a picture of the giraffe's characteristics free from explanatory schemes. This and the article in the previous issue will be incorporated into a monograph in our* Nature Institute Perspectives *series.*

A LONE GIRAFFE BULL stood at the edge of the scrubby bush forest that opened into a grassland. The grasses and forbs were yellowed and brittle. It was August, the beginning of spring, but also the middle of the dry season in the southern African savannah. Many trees and bushes had no leaves, some still bore fruit, and others were just beginning to flower.

The giraffe didn't seem bothered by our presence, although we were off the main tourist track. Since we were quite close, the giraffe's towering height was striking. Long narrow legs carried its barrel-shaped, beautifully brown and white-patterned body high above the ground. Its back sloped downward, extending into the tail with its long strands of wavy hair that nearly reached the ground. Towards the front the body took on more bulk and, sloping steeply upward, merged into the massive and skyward-reaching neck.

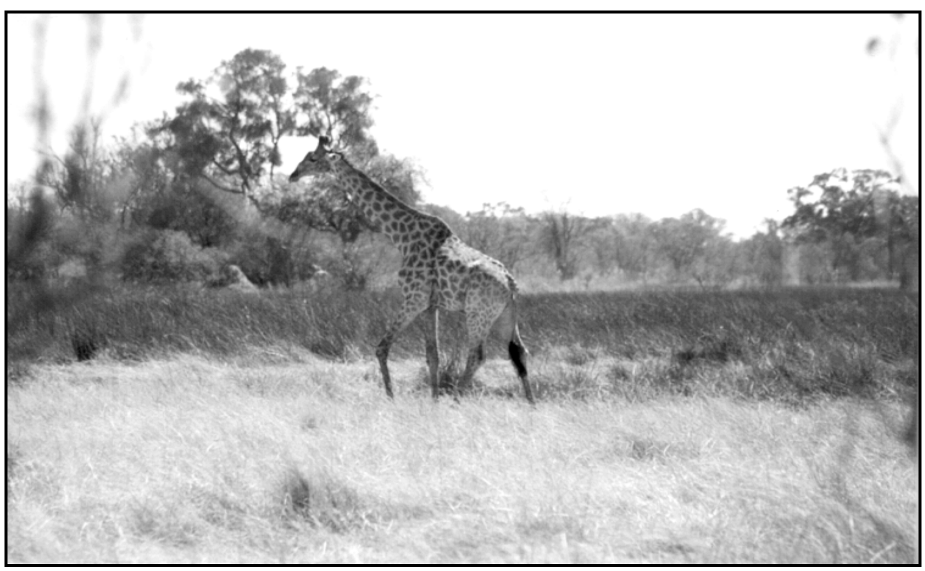
From its lofty perch, the giraffe watched us calmly with its dark, bulging eyes. It was not excited; it was not aggressive. When it turned its head to face us directly, we could see its fine, out-curving eyelashes encircling its attentive eyes. This particular giraffe captured our attention for a good while. It was eating. But it was not feeding on the leaves of trees and bushes, as we'd grown used to seeing. There were no trees or bushes within its reach, and its head was not lowered to the ground grazing. No, this giraffe was chewing on its hardy meal, which was partially sticking out of its mouth. Imagine a giraffe smoking a giraffe-sized cigar and you can get an inkling of the scene. The giraffe was feeding on a sausage tree fruit. These fruit really do look like sausages (or big cigars), and sausage trees hang full of them at this time of year. They are about one to two feet long, two to three inches in diameter and can weigh up to twenty pounds.

About six inches of the long fruit were protruding, so that the other twelve inches or so were in the giraffe's mouth. It was chewing with circling motions of the lower jaw. Every now and again it would raise its head in line with its neck and gulp, as if it were trying to swallow the fruit. But the fruit never budged. We wondered whether it was stuck and were worried, since, at the time, we didn't know that giraffes do eat these fruits during the dry season. But the giraffe didn't look concerned and was apparently in no rush; with a sausage as its meal it didn't need to wander around. I don't know how long we were there, but eventually we moved on, wondering whether the giraffe succeeded in getting this long fruit through its long mouth down into its long throat.

The giraffe is an animal in which everything seems built around lengthening—from its tail hairs to its long eyelashes, from its long legs to its long neck and head. It was an unexpected gift to come across a giraffe that was embodying elongation to the fullest, eating that long fruit of a sausage tree.

The Giraffe Within the Landscape

There is nothing like seeing a giraffe in its natural habitat—dry savannah grassland with groups and thickets of



A lone giraffe walks across an opening in the savannah of Botswana. (Photo: Craig Holdrege) thorny bushes and trees. When a giraffe stands in or is moving across an open grassland, you can see it from far away. It is conspicuous like no other animal. After spotting an individual or group of giraffes when I was observing giraffes in Botswana, I would take my binoculars to view more closely. Invariably I found the giraffes already looking at me (or at least at the land rover I was perched in). The giraffe has the largest eyes among land mammals. Since its eyes are set at the sides of a head that rises five meters above the ground, the giraffe has a very large field of vision. It is keenly aware of moving objects in its visual field. In viewing the giraffe from afar, you have the impression of a lofty creature sensitive to the happenings within its broad horizon.

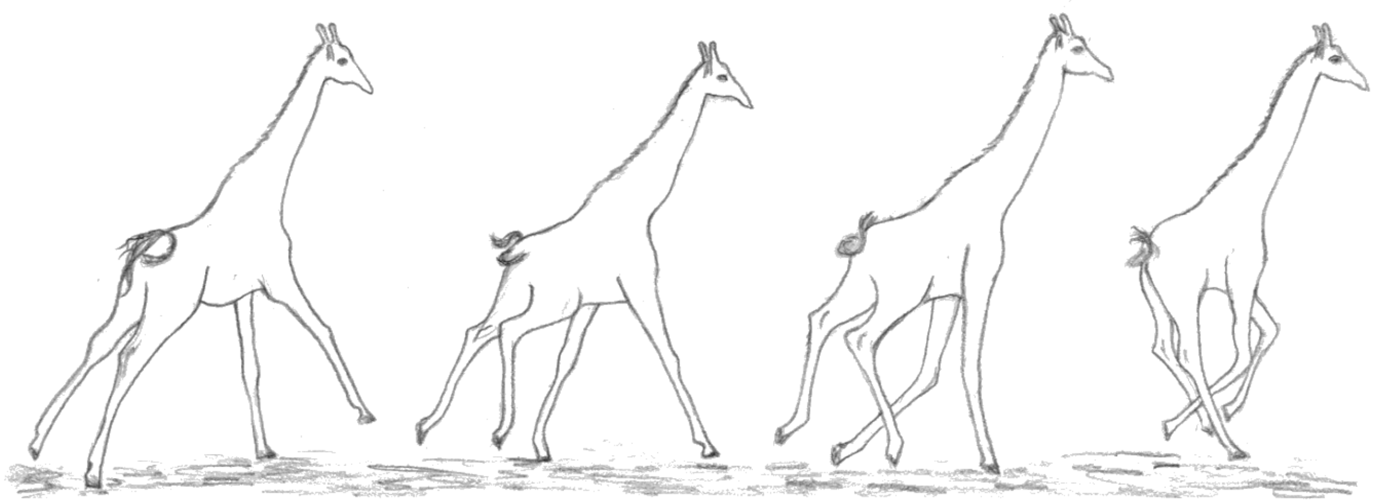
When you leave the open grassland and wind your way slowly through wooded and bush areas, you often come upon giraffes at very close distance without any preparation. Among trees, the giraffe seems to disappear into its habitat—a stark contrast to its visibility in the open landscape. At least two features of its appearance allow it to blend in this way. First, with its long upright legs from which the neck branches off at an angle, the giraffe's form follows the lines of the tree trunks. When as observers we are close to the ground looking horizontally, what we see (or rather overlook until it's very close) are the narrow legs that meld in among the many trunks of the acacia or mopani trees. The second factor is the giraffe's spotted coat. Despite the variety of coat patterns in different populations and subspecies of giraffes, all have in common the brown (varying from reddish to black) spots separated by white spaces or lines. When a giraffe is among trees, this dark-light pattern is similar to the mottled pattern of brightness and shade that plays among the branches and leaves. So with its unique shape and coat pattern, the large giraffe recedes into its wooded environment.

It is also the case that the giraffe does not make much noise, either while feeding (browsing off the trees and bushes) or after it notices you. It may stand and watch you from on high for a moment, swing its head and neck around and then amble off. Rarely it makes a snorting sound during such encounters, but that is usually the limit of its minimal aggressiveness. In contrast, an elephant may tread silently, but it loudly breaks off branches while feeding, and trumpets loudly and makes a mock charge when surprised.

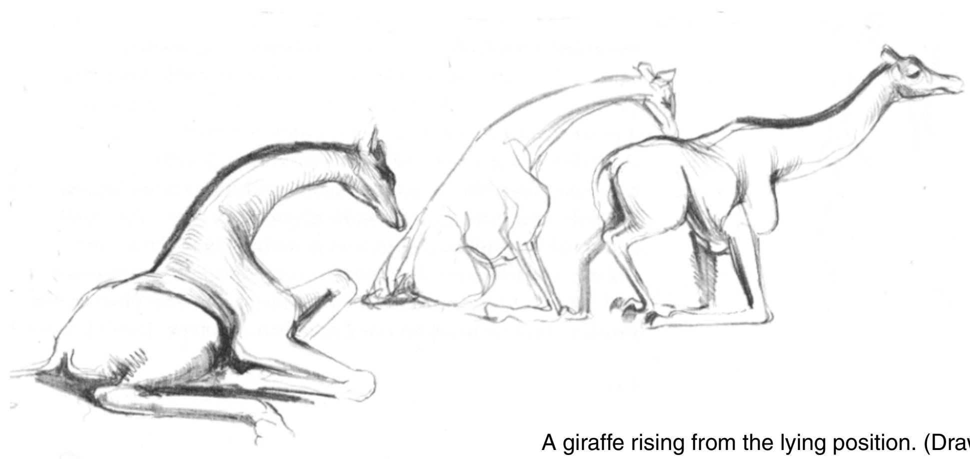
"Giant Speckled Flowers, Floating Over the Plains"[1]

One of the most striking things about the giraffe is the way it moves. An adult giraffe can weigh up to 1,100 kg, yet its movement appears almost weightless. The giraffe has two different gaits—the ambling walk and the gallop. In contrast to most ungulates, the giraffe walks by swinging its long legs forward, first both legs on one side of the body and then both legs on the opposite side. This type of walk is called an

1. Isak Dinesen, quoted in Stevens 1993, p.6.



A galloping giraffe. a): the most extended phase of the gallop as the left foreleg has reached the ground. b): the right foreleg reaches the ground. c): the right foreleg is on the ground and the hind legs swing in. d): the legs are bunched together and the neck is at its most upright as the right hind leg approaches the ground. (Drawings by author after photos in Dagg and Foster 1982, pp. 100-101.)



A giraffe rising from the lying position. (Drawing by Jonathan Kingdon 1989, reprinted by permission from Elsevier.)

amble, and the giraffe has it in common with okapis, camels, and llamas. In contrast, other ungulates walk by simultaneously moving the left front and right rear legs and then the right front and left rear legs. The amble has a flowing, rhythmical quality to it and the giraffe's body and neck swing side-to-side, counterbalancing the one-sided movement of the legs.

The giraffe's legs are longer than any other mammal's, which gives it a very long stride. In addition, its forelegs are longer than its hind legs so that its gait is unlike that of any other mammal. When walking, its rear leg touches the ground about 50 cm (20 inches) in front of the spot from which it lifted its front leg. Because the giraffe is so large, the motion of the legs seems almost in slow motion. And with its center of gravity so high up, and its attentiveness concentrated in the elevated head, the giraffe seems to sweep along, hardly in contact with the earth. It treads on the earth, but it certainly does not appear to be of the earth. As Jane Stevens describes, "I watched as a group of seventeen floated along the edge of a yellow-barked acacia forest" (Stevens 1993, p. 6).

The unearthly quality of movement intensifies when the giraffe accelerates into a gallop. Its stride lengthens even more and all four feet leave the ground. When off the ground, the forelegs reach far forward and the neck becomes more horizontal. The feet come close together when they, one after the next, touch the ground; at this phase of the gallop the neck reaches its most vertical position. The faster the giraffe moves, the more its neck moves down (forward) and up (back). A giraffe can attain a speed of 55-65km/hr. The long swinging movements of both the legs and neck and the rhythmical expansion and contraction (spreading out in thrusting forward and contracting into the vertical while landing) are a fascinating sight. The impression that you are watching an animal in slow motion is accentuated during the gallop.

Dagg and Foster describe the mechanics of the giraffe gallop in more detail:

> The power and weight of the giraffe are more in the forequarters than in the hindquarters, so that the main propulsion for each stride comes from the forelegs. By pressing forward at the beginning of each stride, the neck moves into line with the power stroke. The neck facilitates the movement by shifting the center of gravity of the giraffe's body forward and more nearly over the forelegs. At the end of each stride or leg swing, as the hooves touch the ground again, the neck moves backward in order to slow down the forward momentum of the body and enable the giraffe to keep its balance. (Dagg and Foster, 1982, p. 102)

In other words, the pendulum motion of the neck helps to propel the giraffe forward and aids in maintaining balance. No other mammal's neck plays such a role in forward movement! And in no other mammal do the forelegs give the main propulsive force, a task usually taken on by the rear legs. Thus the giraffe's unique form of motion arises out of the interplay of its unusual characteristics—its long neck, short body, high center of gravity, and long legs.

The giraffe's neck not only plays a role in walking and running, but also is absolutely necessary in aiding a giraffe to stand up, as biologist Vaughan Langman describes:

> A giraffe, unlike most other mammals, is totally reliant on its head and neck to rise from lying on its side. In order to get off the ground, it must throw its head and neck toward its legs and use the force of the throw to bring [the giraffe] to its stomach. To come up to a standing position requires another throw of the head and neck, this time back toward the tail; once again it is the momentum of the head-neck throw which makes it possible for a giraffe to stand [up]. (Langman 1982, p. 96)

The giraffe's neck, which stands out so conspicuously in a morphological sense, also takes on a prominent role functionally in its movement.

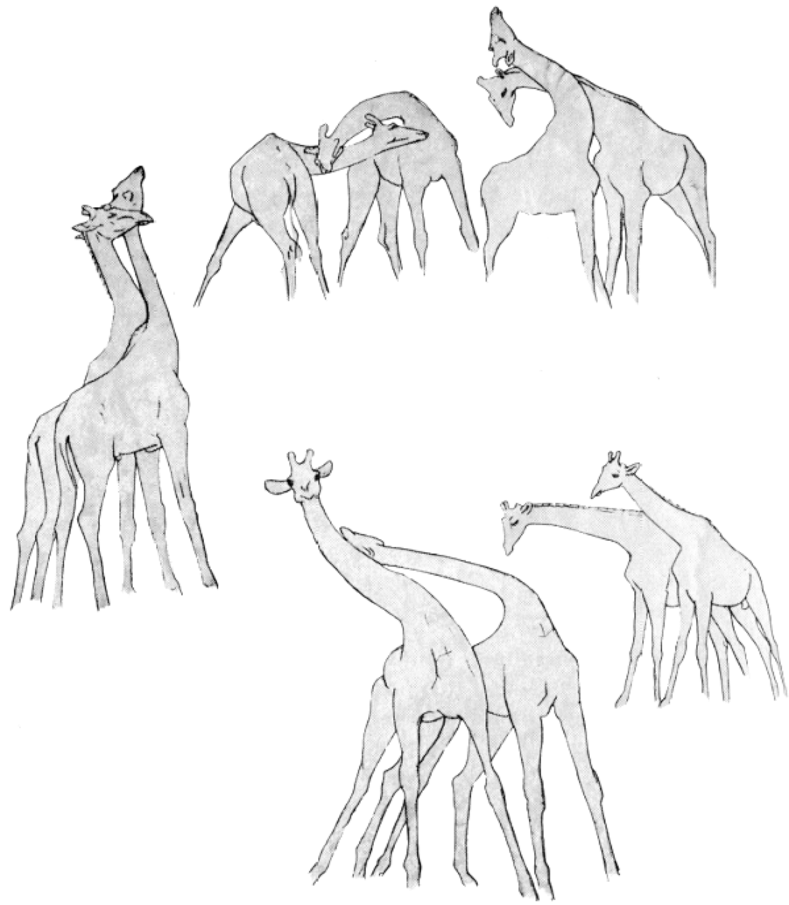
"Necking"

> Movement and counter movement appear rhythmical and synchronized, imparting the sinuous grace of a stylized dance. (Estes 1991, p. 205)

Imagine a grouping of younger and older male giraffes. One animal starts moving closer to another, until the two are perhaps four to five meters apart. He raises his head and neck into an erect posture, emphasizing his height and uprightness. (We might say, anthropomorphically: emphasizing that he's a *real* giraffe.) If the other male responds similarly, they begin walking toward each other, stiff-legged and with legs splayed. They come to stand facing in the same direction, body next to body. They begin leaning and rubbing flanks, necks, and heads against one another. Both giraffes stand with splayed forelegs. One giraffe will swing his neck out to the side and swing it back, making contact with the other's neck. The partner responds with the same kind of neck swing. So ensues the "rhythmical and synchronized…dance" that Estes characterizes.

This "necking behavior," as it is dryly named, can either stop after awhile or transform into a more forceful sparring (Coe 1967). In this case the blows with the head and neck become much more powerful and the slap of contact can be heard far away. When the two giraffes stand side-by-side, but facing in opposite directions, the blows tend to be more violent. Necking bouts may last only a few minutes when one male is clearly dominating the bout. But when the partners are more evenly matched they can last for more than half an hour and they have even been described as going on for hours. Rarely is a giraffe hurt in these necking bouts; usually one of the giraffes simply stops "necking" and wanders off.

Sparring and dominance bouts among males are known from many ungulate species. What's characteristic about this kind of behavior in the giraffe is that the neck plays such a central role. The broad, undulating sweeps of the neck have, as Estes expressed it, "sinuous grace." The character of the giraffe comes clearly to expression in this remarkable form of behavior.



"Necking" giraffes. (Reprinted from Kingdon 1989 with permission from Elsevier)

Lofty—and at a Distance

With its "lofty stature" (Darwin), the giraffe commands a large overview. It's not surprising that the sense of sight plays a dominant role in the giraffe's life. It can see fellow giraffes, but also predators such as lions, from far away. The giraffe's vision is keen—as already mentioned, a giraffe usually sees you before you see it. Experiments in captivity indicate that giraffes also see colors (Backhaus 1959).

Giraffes are not solitary animals, living as they do in herds of varying sizes (often between ten and fifty animals). But as biologist Richard Estes puts it,

> The giraffe is not only physically aloof but also socially aloof, forming no lasting bond with its fellows and associating in the most casual way with other individuals whose ranges overlap its own. (Estes 1991, p. 203)

Giraffe herds are more accurately described as loose groupings, since their composition continually changes. Groupings rarely stay the same for more than part of a day. In one case, a female giraffe was observed on 800 consecutive days and was only found twice in a group that remained the same for twenty-four hours. As Estes remarks, with regard to herd structure and composition, "variability is the only rule" (Estes 1991, p. 204).

Even within the momentary grouping, giraffes tend to keep physical distance from each other, remaining within eyesight but often not closer than twenty feet apart. They overcome these distances when feeding together from the same trees or shrubs. Under these circumstances one can see giraffes closely grouped, although rarely touching each other.

As we might expect, vision plays an important role in communication between giraffes:

> Staring seems to be a favorite form of giraffe communication. There are what look to human observers like hostile stares, come-hither stares, go-away stares, there's-an-enemy stares. When giraffes spot lions in the grass, a steadfast gaze alerts dozens of other giraffes that may be scattered over a square mile of savanna. Giraffe mothers stare at other adults to warn them away from calves. (Stevens 1993, p. 10)

The dominant role of vision goes hand-in-hand with a reduction in importance of the sense of smell, which is so important in most other mammals:

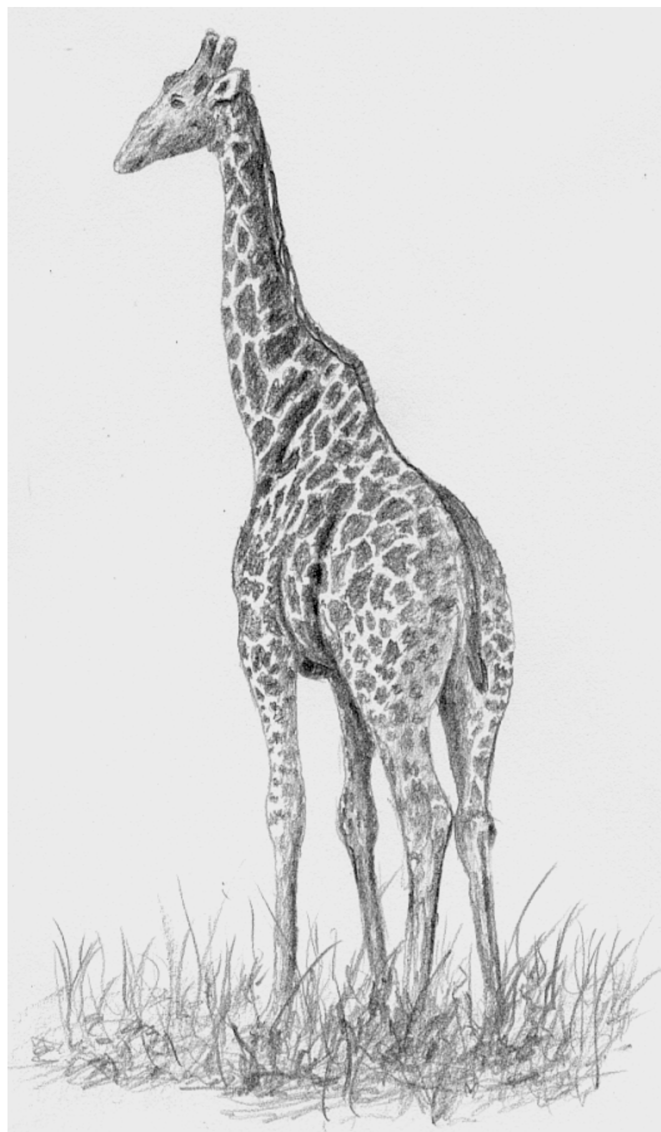
> The sense of smell recedes in importance and is limited to scents in rising air currents.… The unique body of the giraffe causes the sense of smell to play such a small role. Scent-marking of territory falls away…[and] scent glands are lacking. Extensive visual communication compensates the lack of olfactory communication. Tail movements serve as signals. (Krumbiegel 1971, p. 52)

With its body high off the ground and the head resting even further up on the long neck, the giraffe distances itself from the rich world of smells near the ground, a world in which most other mammals are immersed. It is a telling fact that the end of the giraffe's nose and muzzle is dry in contrast to the moist nose and muzzle of most other ruminants.

Touching and rubbing are also not typical forms of giraffe social behavior. They occur usually only between cow and calf, between "necking" males (see above), and before and during mating. Otherwise giraffes prefer distance. You don't see giraffes lounging around with necks resting on the backs of fellow herd members—a typical sight among zebras.

It is interesting in this connection that giraffes rarely drink. I have discussed (Holdrege 2003) their awkward manner of splaying their forelegs to reach down to drink water, as if their ungainly posture were telling us about their lack of need for drinking. (Giraffes take in substantial amounts of water from the leaves and shoots they browse.) Giraffes also do not bathe in watering holes or rivers and rarely swim. If you picture the giraffe immersed in water, with its high center of gravity, it's hard to imagine how it could keep its balance. The giraffe's gestalt is definitely not adapted to life in water!

The quiet, sensitive aloofness of the giraffe stands out more when we think, by way of contrast, of the elephant. Elephants live in tightly bonded family groups in which the members are in close physical contact. They rub up against each other and caress and slap each other with their trunks. They are continually pulling in the scents of their



A lone male giraffe in Botswana. Note that the tail is missing its long hairs, which the giraffe probably lost when its tail was grabbed by a lion. (Drawing: Craig Holdrege) surroundings through their trunks. An elephant will smell you before it sees you; its eyes are definitely not its dominant gateway to its surroundings. Elephants also love water and, when they can, bathe every day. Elephants are about contact and immersion; giraffes maintain more distance. Although giraffes and elephants often inhabit the same area, qualitatively they live in very different worlds.

In my forthcoming monograph on the holistic biology of the giraffe, I will complete this portrayal of the giraffe by discussing in detail its peculiar morphology, its feeding ecology, and patterns within the evolution of the giraffe family.

References

Backhaus, D. (1959). "Experimentelle Prüfung des Farbsehvermögens einer Masai-Giraffe." *Z. Tierpsych.* vol. 16, pp. 468–477.

Coe, Malcolm J. (1967). ""Necking" Behavior in the Giraffe." *Journal of Zoology, London* vol. 151, pp. 313–321.

Dagg, Ann Innis, and J. Bristol Foster (1982). *The Giraffe: Its Biology, Behavior and Ecology.* Malabar, Florida: Krieger Publishing Company.

Estes, Richard Despard (1991). "Giraffe and okapi." In: Estes, Richard Despard, *The Behavior Guide to African Mammals*. Berkeley: University of California Press, pp. 201–207.

Holdrege, Craig (2003). "The Giraffe's Short Neck: Why Evolutionary Thought Needs a Holistic Foundation." *In Context* #10 (Fall 2003), pp. 14-19. (available online at: http://www.natureinstitute.org/pub/ic/ic10/giraffe.htm)

Kingdon, Jonathan (1989). *East African Mammals*, Vol. IIIB (Large Mammals). Chicago: University of Chicago Press.

Krumbiegel, Ingo (1971). Die Giraffe. Wittenberg (Germany): A. Ziemsen Verlag.

Langman, Vaughan A. (1982). "Giraffe Youngsters Need a Little Bit of Maternal Love." *Smithsonian* vol. 12, pp. 94-103.

Stevens, Jane (1993). "Familiar Strangers." *International Wildlife* Jan/Feb, pp. 5-10.

(Photo: Craig Holdrege)

Quantum Puzzles

Steve Talbott

The following is adapted from a fuller essay (tentatively entitled "Unfulfilled Revolution") scheduled for publication in The Nature Institute's online *NetFuture* newsletter. The essay originated as a commentary on *The New Physics and Cosmology: Dialogues with the Dalai Lama,* edited by Arthur Zajonc (Oxford: Oxford University Press, 2004).

By the beginning of the twentieth century, the paradigm of classical physics and cosmology, founded on mechanistic models, dominated not only the hard sciences, but also the life sciences. Further, since a mind that insists on contemplating the world in a mechanistic fashion forces itself to function mechanistically, it is no accident that the reigning paradigm was looking more and more attractive even as a framework for understanding the mind.

The early decades of the twentieth century shook this simple and comfortable world outlook with a disturbing force we have still barely begun to comprehend. It is hard, Arthur Zajonc writes, to overestimate the significance of quantum theory and relativity. These theories challenged mechanistic accounts of the cosmos and granted unexpected significance to the human observer. "The ramifications of twentieth-century discoveries for physics and cosmology have been enormous, changing our very notions of space and time, the ultimate nature of matter, and the evolution of the universe." The philosophical implications are, as Zajonc adds, "still being sorted out."

Or being ignored. The stance of our culture toward the revolution in physics is oddly schizophrenic. On the one hand, we have been treated, since at least the 1960s, to a parade of popularizations glorifying the counter-intuitive or bizarre results of what must seem to the layman an unapproachable science. These authors tell us of esoteric physicists in saffron robes, masters of zen and the tao, who from on high have stolen forbidden glimpses of the cosmic dance.

But little of this drama, and none of its real significance, seem to have penetrated the public's day-to-day consciousness of science. This is evident, above all, in the schools, where the pictures with which we saturate the imaginations of children—neat pictures of atoms and particles whirling in the void—are more representative of nineteenth-century mechanism than twentieth-century revolution. It seems at times that the awe-inspiring and incomprehensible wonders of the popularizers serve primarily to add a mystical or religious aura to the otherwise humdrum, soul-paralyzing dogma cluttering our minds in the name of science.

The thought habits of these past few hundred years are, it appears, deeply ingrained. How they might be transformed in accordance with the knowledge we now have, and whether the lay public can participate in the transforming conversations — or instead must be excluded because of the recondite subject matter—these are fascinating questions upon which *The New Physics and Cosmology* bears directly. For it documents the attempt by several contemporary physicists to convey some of the content of their discipline to the Dalai Lama and to engage this penetrating thinker in discussion of the scientific and philosophical issues raised. We are allowed, as it were, to learn along with the Tibetan monk, and to discover whether the conversation is one into which we, too, might enter.

Besides Zajonc, who is a professor of physics at Amherst College, our companions in this exercise include several other quantum physicists and cosmologists of note. For example, Piet Hut is a professor of astrophysics and interdisciplinary studies at the Institute for Advanced Study in Princeton. David Finkelstein is the long-time editor of the *International Journal of Theoretical Physics*. And Anton Zeilinger, formerly director of the Institute for Experimental Physics at the University of Innsbruck, Austria, is now a professor of physics at the University of Vienna.

In this article I do not discuss the contributions from the side of Buddhism, which I am unqualified to assess. I should add, however, that the Dalai Lama makes for an undeniably engaging conversational partner.

Particles and Waves

There is a crucial experiment in quantum physics called the "double-slit" or "two-hole" experiment. In the briefest of terms (and employing the common terminology): if you fire a narrow beam of photons at a screen with two small holes in it, the photons going through these holes will form an interference pattern on a second screen placed behind the holes.

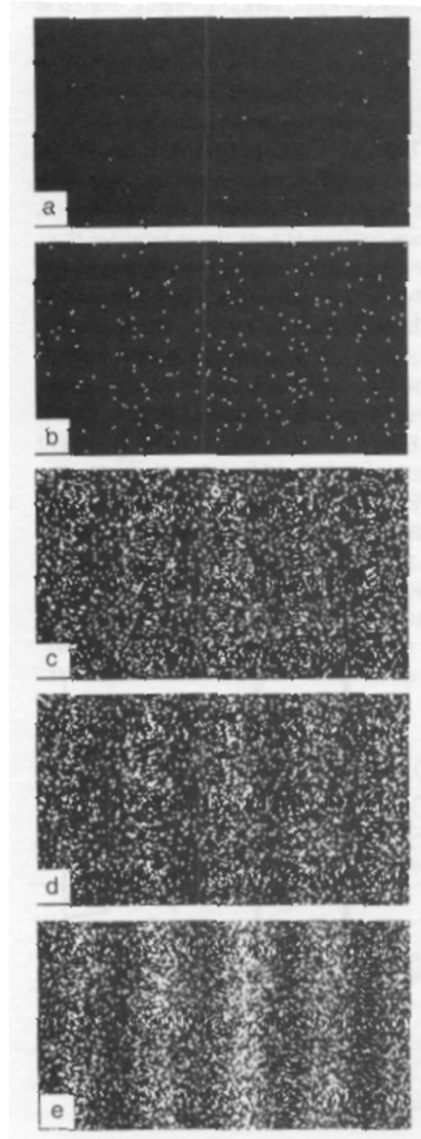
This pattern, consisting of alternating light and dark bands, is exactly what you would expect if the photons were in fact waves passing through both holes at once and then interfering with each other. But at the same time—and this is the beginning of the mystery—each individual photon makes a discrete impact at a particular location, as if it were not a wave, but a particle.

Moreover, you can send the photons toward the holes one at a time, with each making a single flash on the screen (or spot of light on a photographic plate). In this case, as physicist John Gribbin explains,

> "You might think that each particle must go through only one or the other of the two holes. But as more and more spots build up on the screen, the pattern that emerges is the classic interference pattern for waves passing through both holes at once. The quantum entities not only seem to be able to pass through both holes at once, but to have an awareness of past and future, so that each can 'choose' to make its own contribution to the interference pattern, in just the right place to build the pattern up...."
>
> Gribbin goes on:
>
> There's more. If you think this is fishy, and set up a detector to tell you which hole each particle is going through, all of this mysterious behaviour disappears. Now, you do indeed see each particle ... going through just one hole, and you get two blobs of light on the detector screen, without interference. The quantum entities seem to know when you are watching them, and adjust their behaviour accordingly .... Each single quantum entity seems to know about the whole experimental set-up, including when and where the observer is choosing to monitor it, and about the past and future of the experiment" (Gribbin 2000, p. 113).

You will find the same behavior with electrons and, indeed (at least in principle), with every other particle or collection of particles. Calling this experiment the "central mystery" of quantum mechanics, Richard Feynman once remarked that it is "impossible, *absolutely* impossible, to explain in any classical way .... In reality, it contains the *only* mystery ... the basic peculiarities of *all* quantum mechanics" (Feynman, Leighton, and Sands, vol. 3, p. 1-1). Feynman was emphatic about this, later writing that

> any other situation in quantum mechanics, it turns out, can always be explained by saying, "You remember the case of the experiment with two holes? It's the same thing." (Feynman 1965, p. 130)



When electrons are fired one at a time through the two holes of the classic double-slit experiment, they progressively build up the interference pattern shown in these photographs from the Hitachi Research Laboratories. The pattern is like the one formed when a wave passes through two holes, whereupon the secondary waves issuing from the holes interfere with each other. However, each electron makes a single spot of light on the detector screen as if it followed a well-defined, particle-like trajectory through one hole or the other.

A common way of stating the puzzle runs something like this: If the electron is a particle, how does each one "know" where to land in order to build up the interference-like pattern? This seems to require that it "remember" where all the others have landed. On the other hand, if the electron is a wave, how does it manage to register an impact at a single spot? Another way of stating the puzzle: So far as any scientific determination of cause and effect is concerned, every individual electron impact is absolutely random. Yet the result of all the impacts is a non-random pattern. How can this be?

A Spirit of Inquiry

There is good reason to underscore this importance of the double-slit experiment since, as an observable phenomenon, it is not terribly difficult to grasp. It can easily be presented to high school students—and, most importantly, presented as a set of questions. Science could thereby become for the student a living inquiry rather than a logically systematized body of truth. If the stimulating questions posed by the "central mystery" of physics have not in fact become central to the public's consciousness of science, we can only assume a massive failure of education on the part of the scientific community. And a huge lost opportunity.

The counter-intuitive nature of the double-slit experiment is, after all, a reason *for* presenting it to the student, not a reason for avoiding it. Evidently our intuitions need re-educating. A science realistic in its self-appraisal might find in this a reason for modesty. One of the appealing aspects of *The New Physics and Cosmology* is that we encounter leading experimentalists and theoreticians who *have* gained from their work a sense of modesty. The phrase "we don't understand" is not foreign to these pages. When told that a certain answer might arrive in fifteen years, Anton Zeilinger responds,

> That has been said very often in the history of science: Come back in fifteen years. And the answer did not come; the problem just sounded more complicated. I remember people saying, "Give me one piece of the moon and I will tell you the history of the universe." It did not happen that way. We got one piece of the moon, but it turned out to be more complicated.

It is occasionally startling to hear these physicists expressing themselves, not only as scientists, but also as human beings. David Finkelstein suggests that "far from being strangers in the universe, we are actually part of the law that governs it, and we help make the law that determines our own lives." And he continues:

> Things like love and meaning are presumably not there under the microscope. But we shouldn't be surprised that we don't find them there because they are behind us in the home from which we come.

Likewise, Piet Hut, noting that science "cannot say anything yet about the original raw experience" upon which it is based, predicts that "the next relativity theory ... will include a relativity between the object and the subject, between the physical and the mental." He confesses, "I cannot jump yet. I am a little bit too scared to make such a big jump." Yet he can recognize in "the Tibetan notion of the sameness of outer and inner space ... something very similar to what I expect to happen in the language of science in the next hundred years or so."

Contradictions

Unfortunately, the spirit of openness and dialogue evident in this book is not always present within science as a whole. A tendency toward compartmental isolation and rigidity of thought mars what would otherwise be an endlessly stimulating intellectual landscape. How is it, for example, that reputable physicists can posit consciousness as a fundamental category—or even as the ultimate source of reality—yet in the other sciences (which strain so hard toward the authoritative aura of physics) any suggestion that consciousness is primary and irreducible remains taboo? Apparently the authority being honored derives from the physics of yesterday, not the knowledge and open-ended inquiry of the leading thinkers in physics today.

Similarly, we live in a time when Feynman can say of quantum mechanics, "how does it really work? What machinery is actually producing this thing? Nobody knows any machinery" (1965, p. 145). In fact, if there is one thing quantum mechanics seems intrinsically unable to present us with, it is anything remotely resembling machinery. And yet, too many smug scientists, trusting to a bottom-up, material-building-block view of the world, somehow manage to overlook the absence of mechanical building blocks at the bottom as they speak confidently of the triumph of mechanism. Thus, Harvard biologist E. O. Wilson casually remarks that "People, after all, are just extremely complicated machines." And in the words of robotics expert Rodney Brooks, "The body, this mass of biomolecules, is a machine that acts according to a set of specifiable rules .... We are machines, as are our spouses, our children, and our dogs...."

One wonders how these commentators have managed to avoid the entire history of twentieth-century physics. But it turns out that ignoring what one prefers not to look at is almost a defining characteristic of much science today.

Fruitful Ambiguities

A great deal of misunderstanding about the significance of physics arises from confusion over the notion of explanation. Physicists unanimously assure us—and rightly so—that quantum mechanics provides methods of remarkable universality. No phenomenon has ever been encountered for which these methods of analysis and statistical prediction do not work. This leads researchers to say, "As far as we can tell, there is no experiment that quantum theory does not explain, at least in principle" (Herbert 1985, p. 44).

That is fine, but we need to recognize the extreme narrowness and shallowness characterizing this particular notion of "explanation." After all, from another standpoint we can say that quantum theory explains almost nothing. It does not, for example, explain the red color I see—or, for that matter, any of the observable, sensible reality science was originally intended to explain. This experiential realm (which is in fact the only realm we have) has mostly been set aside and bracketed as lying outside science proper. So when Piet Hut imagines a science that can mediate "between the object and the subject, between the physical and the mental," he is imagining a revolution that will dwarf anything the twentieth-century has seen. One appreciates his fear of making the leap. Explaining an observed phenomenon—if we ever begin to make the attempt—will radically differ from merely identifying certain quantitative and statistical regularities abstracted from it. (See "Do Physical Laws Make Things Happen?" available at http://qual.natureinstitute.org.)

One way to picture the limitations of today's science is by imagining a logical-mathematical grid laid over the world. The quantitative perfection of our explanations can then be seen as a function of the infinitesimal thinness and precision of the grid lines. But because of this same thinness, we can also say that the phenomena we are viewing almost completely escape the grid, falling between the lines. And if we thicken the lines so as to "cover" more of the phenomena, we find that their precision disappears. The grid's logical and numerical "joints," so to speak, are no longer exact; with thick lines, we can no longer specify precise and unambiguous points where the lines cross.

There is, in other words, a trade-off between a kind of universal precision that treats certain mathematical features of phenomena but leaves the phenomena themselves unaccounted for, on the one hand, and, on the other hand, a more adequate reckoning with the phenomena—a reckoning, however, that sacrifices the rigidity and narrow precision of the logical grid. The Chinese scholar, Tu Weiming, hinted at this when he remarked to the Dalai Lama and other symposium participants, "It is [the] ability to appreciate fruitful ambiguities, rather than to search for that which is true and certain in a limited sense, that opens up all kinds of new possibilities."

Polar Opposites

The truth underlying Weiming's remark is widely under-appreciated today. It is the truth of a polar opposition between meaning and accuracy, or between depth of insight and the ease of articulating and conveying that insight (Barfield 1967, pp. 35ff.; Barfield 1973). The scientist and policymaker, Warren Weaver, alluded to this opposition when he wrote,

> One has the vague feeling that [mathematically defined] information and meaning may prove to be something like a pair of canonically conjugate variables in quantum theory, they being subject to some joint restriction that condemns a person to the sacrifice of the one as he insists on having much of the other. (Shannon and Weaver 1963, p. 28)

Weaver's comment occurred in an introduction to *The Mathematical Theory of Communication*—a treatise explicitly stating that "the semantic [meaningful] aspects of communication are irrelevant to the engineering aspects." The treatise, of course, is about the engineering aspects. This decision to ignore meaning in the pursuit of quantitative exactness—a decision widespread throughout science—makes it obvious why physicists have been brought to the point where an understanding of the character of reality seems unreachable. Their explanatory "grid" simply leaves too much of the world out of sight.

All this makes two salient facts of contemporary physics wholly compatible:

> We have a precisely formulated quantum mechanics of seemingly perfect and universal applicability.
>
> We have physicists proposing various understandings of reality that are as wildly imaginative, outrageous, diverse, bizarre, and mutually contradictory as any of the proposals ventured by medieval metaphysicians.

On this last point you need only consider the debates over questions such as the following: Are the world's laws founded upon absolute randomness? Does reality consist of a steadily increasing number of parallel universes? Can time flow backward? Are there "wormholes" that take a shortcut through spacetime, linking two different times? Is there a shadow universe sharing gravity, but no other forces, with our own universe? Can we know the real world at all? Does observation create reality? Does consciousness create reality?

Such questions are posed by some of the same physicists who assure us they are closing in upon a "final theory of everything"! "Everything" in this case seems perilously close to "nothing"—just as a grid of universal extent and absolutely precise lines "covers" everything and nothing at all.

The extraordinary narrowness of much scientific explanation—especially in the hardest sciences—seems lost on most scientists. The undeniable satisfactions of precision and of successful quantitative prediction blind them to the fact that they have, with their unambiguous theories, largely abandoned the world we actually observe. This is why questions about reality or the meaning of quantum mechanics lead so quickly to unrestrained metaphysical fantasy. There is not enough reality in the parameters of this science to constrain interpretation. Without a reversal of four hundred years of scientific history—without a willingness to transform a science of quantities alone into a science of phenomena—one can only remain pessimistic in the face of Zajonc's expressed hope that

> the fluctuations of concepts and opinions only indicate a violent process of transformation which in the end will lead to something better than the mess of formulas that today surrounds our subject.

The New Physics and Cosmology itself does not attempt to point the way toward a qualitative science. But at least it gives us reason to think there might be an openness to such a science among those researchers who have confronted most dramatically the unexpected boundaries of the science we now have.

A final note. In my judgment, the book does not fully succeed in its effort to present key aspects of modern physics to the layman. It proceeds too quickly from sketchy descriptions of scientific experiments to a discussion of their meaning. It would be wonderful to have a book that more thoroughly presented the experiments, developing the philosophical issues in a closer and more detailed relation to those experiments—a book less wide-ranging in speculative coverage, perhaps, but more revealing of the science. Nevertheless, the discussion we are given in this book is full of rewarding insights and surprises.

References

Barfield, Owen (1967). *Speaker's Meaning*. Middleton CT: Wesleyan University Press.

Barfield, Owen (1973). *Poetic Diction: A Study in Meaning*. Middletown CT: Wesleyan University Press.

Feynman, Richard P., Robert B. Leighton, and Matthew Sands (1963). *The Feynman Lectures on Physics* (three volumes). Reading MA: Addison-Wesley.

Feynman, Richard (1965). *The Character of Physical Law*. Cambridge MA: MIT Press.

Gribbin, John (2000). *Q is for Quantum: An Encyclopedia of Particle Physics*. New York: Simon and Schuster.

Herbert, Nick (1985). *Quantum Reality: Beyond the New Physics*. New York: Doubleday.

Shannon, Claude E. and Warren Weaver (1963). *The Mathematical Theory of Communication*. Urbana IL: University of Illinois Press.

(Genes Are Not Immune to Context, continued from page 12)

The examples I have described show how strongly the environment influences the activity of genes, induces changes within genetic structures (mutations), and stimulates the movement of genes between bacteria. Bacteria are in continual interplay with their environment, actively responding to changing conditions. And this responsiveness and flexibility includes genes. If we release genetically engineered bacteria into the environment, there is little doubt that in time they will be passing their genes to other bacteria, as well as receiving genes from other bacteria and mutating according to changing circumstances. Whether the manipulated foreign genes they carry will be exchanged, or how they may affect or be affected by the dynamics of genetic responses to changing environments is completely open. But two things we can know for sure: these genes will not function immune to the changing circumstances and things will happen that no one expects or can foresee. I'm not saying this to promote fear, but to dissolve the illusion that we can keep under control what we have released into the world in this way. Genes are robust, but they are also part of the world.

References

Beaber, John W. et al. (2004). "SOS Response Promotes Horizontal Dissemination of Antibiotic Resistance Genes." *Nature* vol. 427, pp. 72- 74.

Bjedov, Ivana et al. (2003). "Stress-Induced Mutagenesis in Bacteria." *Science* vol. 300, pp. 1404-1409.

Björkman, J. et al. (2000). "Effects of Environment on Compensatory Mutations to Ameliorate Costs of Antibiotic Resistance." *Science* vol. 287, pp. 1479-1482.

Bull, James and Bruce Levin (2000). "Mice Are Not Furry Petri Dishes." *Science* vol. 287, pp. 1409-1410.

Luria, S.E. and M. Delbrück (1943). "Mutations of Bacteria from Virus Sensitivity to Virus Resistance." *Genetics* vol. 28, pp. 491-511.

Rosenberg, Susan M. (2001). "Evolving Responsively: Adaptive Mutation." *Nature Reviews Genetics* vol. 2, pp. 504-515.

Wirz, Johannes (1998). "Progress Towards Complementarity in Genetics." *Archetype* Sept (No. 4), pp. 21-36. Available online: http://www.ifgene.org/wirzcomp.htm

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