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What Do Organisms Mean?

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***Editor's Note**: This is the third in a set of essays by Mr. Talbott dealing with the new understanding of living organisms being urged upon us by the intense ongoing work in molecular biology. The previous installments were "Getting Over the Code Delusion" (Summer 2010) and "The Unbearable Wholeness of Beings" (Fall 2010).*

If a single problem has vexed biologists for the past couple of hundred years, surely it concerns the relation between biology and physics. Many have struggled to show that biology is, in one sense or another, no more than an elaboration of physics, while others have yearned to identify a "something more" that, as a matter of fundamental principle, differentiates a tiger—or an amoeba—from a stone. The former, reductionist aim can easily seem to ignore what is special about living creatures—and above all to ignore the way meaningful human experience seems to transcend the kind of lawfulness we observe in inanimate physical objects. But, on the other hand, scientists who attempt to articulate a principle differentiating the living from the non-living have all too often posited some kind of special matter or vital force that no one ever seems able to identify.

We discussed in previous articles how, whatever their belief in these matters, biologists today—and molecular biologists in particular—routinely and unavoidably *describe* the organism in terms that go far beyond the language of physics and chemistry. Words like "stimulus," "response," "signal," "adapt," "inherit," and "communicate," in their biological sense, would never be applied to the strictly physical and chemical processes in a corpse or other inanimate object. But they are always employed in attempts to understand the living organism. The prevalent descriptions portray the whole organism as an active unity, with powers of regulation and coordination intelligently directed toward the achievement of the organism's own ends. Further, we noted that such descriptions, rooted as they are in the observable character of the organism, show no sign of being reducible to less living terms or to the language of mechanism.

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But this immediately raises a suspicion of vitalism in the minds of many scientists. Who, after all, is this organism? And by what special powers does it "regulate," "integrate," "respond," and "communicate"? Bear in mind, however, that these questions press just as urgently upon the conventional molecular biologist as on the suspected vitalist. After all, the loaded terminology comes straight from the laboratory, where researchers are trying to make sense of what they see.

A subject possessing a power of agency adequate to regulate or coordinate at the level of the whole organism looks for all the world like what has traditionally been called a *being*. But you will not find biologists speaking of beings. It's simply not allowed, presumably because it smells *too* explicitly of vitalism, spiritualism, the soul, or some other appeal to an immaterial reality. We will see later what extraordinary confusion bedevils this attitude, but for now let us simply yield to the biologist's language of choice, provisionally defining a "being" as "whatever makes sense as the subject of all those terms of agency found in every biological research paper." What, or who, is capable of all the highly directed activity of cell and organism? We will leave aside for now any features of that agency other than ones for which the life scientist has vouched.

To think of it positively: We are looking for a way to justify the standard language of biological theory and description. After all, a lot of experiment and observation has led to this language; if we start with it, we will surely gain valuable clues about the being of the organism. For example, the language tells us that every organism discriminates in many circumstances between health on the one hand and disease or injury on the other, and acts flexibly and intelligently—within its own limits and based on the particulars of its disorder (which may involve conditions it has never encountered before)—to restore health. More generally, it pursues a coherent path of development and self-maintenance, and manages to produce new life from existing life via intricate processes at the molecular, cellular, and behavioral levels.

The biologist's "being"—the subject of those verbs of agency—is also at home with meaning, or information, continually transmitting and receiving it, extracting it from or imposing it upon the environment, interpreting it in light of its own needs, acting on it, distinguishing the relevant from the irrelevant. If the biological literature is to be believed, the organic being in some sense perceives, knows, and responds appropriately to the meanings of diverse stimuli.

This being is also said to be a self—whatever the self is that engages wholesale in "self-organization." It does so in part by sponsoring many partial and subordinate "selves," as when one speaks of self-organizing neural networks, self-organizing chromosome territories, self-organizing tissues, self-organizing protein structures, and so on. And it may even participate in a superordinate self: ants are sometimes said to be part of a "self-organizing ant colony."

Such, at least, is the being we are handed by biologists. Not unanimously in all details, to be sure, and in need of critical assessment without a doubt. But it's a place to start. Our aim is to locate this being of the organism a little more comfortably within the landscape of an acceptable science—locate it in a way that remains faithful to observation while sparing biologists any embarrassment at their own language. It will require a considerable journey.

Two Ways of Explaining

We commonly explain occurrences by saying one thing happened because of—due to the cause of—something else. But we can invoke very different sorts of causes in this way. For example, there is the *because* of physical law (the ball rolled down the hill *because* of gravity) and the *because* of reason (he laughed at me *because* I made a mistake). The former hinges upon the kind of necessity we commonly associate with physical causation; the latter has to do with what makes sense within a context of meaning.

Any nuance of meaning coming from any part of the larger context can ground the *because* of reason. "I blushed because I saw a hint of suspicion in his eyes." But I might not have blushed if his left hand had slightly shifted in its characteristic, reassuring way, or if a rebellious line from a novel I read in college had flashed through my mind, or if a certain painful experience in my childhood had been different. In a meaningful context, there are infinite possible ways for any detail, however remote, to be connected to, colored by, or transformed by any other detail. There is no sure way to wall off any part of the context from all the rest.

The Canadian cognitive scientist and philosopher, Zenon Pylyshyn, once neatly captured the distinctiveness of the *because* of reason this way:

> Clearly, the objects of our fears and desires do not cause behavior in the same way that forces and energy cause behavior in the physical realm. When my desire for the pot of gold at the end of the rainbow causes me to go on a search, the (nonexistent) pot of gold is not a causal property of the sort that is involved in natural laws.[1]

The *because* of reason does not refer to mere "logic" or "rational intellectuality." Nor need it imply conscious ratiocination. It is constellated from the entire realm of possible meaning, including such things as our desire for pots of gold or our subconscious urges toward violence. I will therefore refer interchangeably to the *because* of reason and the *because* of meaning, by both of which I refer to all the semantic relations and connotations, all the significances, that weave together and produce the coherent tapestry of a life, or of any other expression of meaning, such as a profound text—say, Aeschylus' *Agamemnon* or Lincoln's Gettysburg Address, or, for that matter, the text of a biological description.

Meaning is notoriously difficult to define—and, in fact, meaning lies at the opposite pole from precise definition. Words gain fullness of meaning only when they are removed from the dictionary and placed in a concrete context, where an interplay of qualities, connotations, suggestions, and metaphorical juxtapositions enables the words to interpenetrate and pulsate with many-dimensioned significance. To "nail something down" in a definition is rather like removing all the overtones from what had once been the richly resonant song of a violin string in order to get a precise, definable rate of vibration. Qualities are reduced to number. As semantic historian Owen Barfield has pointed out, every effort at definition, to the degree it achieves the desired endpoint of abstract, decontextualized precision, becomes mere counting.[2] Water, for example, might be defined in terms of boiling point, melting point, density, transparency (percent transmission of light), and so on.

But despite the loss of meaning in the very attempt to define it, we all have a certain sense for what meaning is, because we all know *what we mean* when we speak.

By contrast, the *because* of physical law applies to things that do have more or less precisely defined and delimited relationships, which therefore lack a meaning-driven character. We need not appeal to "what makes sense" in a larger, more richly expressive context, because a proposed physical law is either "obeyed" or not, despite any look of the eyes or gesture of the hand. A thrown ball respects the law of gravity even if a strong wind is blowing it this way or that. Whereas each detail of a meaningful text gains its significance from the way many contextual elements color and modify each other, we observe the lawfulness of a physical event by isolating (as far as we can) a precisely defined and invariant relationship. The physicist's strong preference is for strict mathematical laws.

Meaning is inseparable from language. But it will prove important to understand that, in distinguishing the *because* of reason from that of physical law, we are not distinguishing the language-like from the non-language-like. Rather, the relation between the two *becauses* is more like the relation between a full-bodied language, on the one hand, and a syntax or reduction of that language, on the other. Mathematics, logic, grammar, algorithmic formalisms—these are examples of such reductions. They give us a kind of generalized skeleton abstracted away from all the concrete expressive potentials of the language. And while these reductions are severely restricted in their ability to describe or characterize the fullness of the phenomenal world, they serve very well to capture the lawfulness we associate with what are often called the "mechanistic" aspects of the world.

Here, then, is the point. What distinguishes the language of biology from that of physics is its free and full use of the *because* of reason. Where the inanimate world lends itself in some regards to application of a "deadened," skeletal language—a language that perhaps too easily invites us to think in terms of mechanisms—the organism requires us to recognize a full and rich drama of meaning.

And so when we ask whether a protein has folded *correctly*, we're not suggesting it may have rashly disregarded the laws of physics. Its respect for the syntax of a physical law is not the issue we're addressing. We want to know something much more plastic—more plastic in the way that meaning is more plastic than a rigid grammar or mathematical formula. That is, we want to know whether the folding is consistent with—serves the needs of and is harmonious with—the coherence and the active, self-expressing identity we recognize in the surrounding context. It's a context and an identity whose qualities and intents differ greatly from a snake to a lion, from a German shepherd to a golden retriever, or from a lung to a kidney. Likewise, when we inquire into the communication between cells, we are not merely curious about the physical impact of molecular projectiles fired from one cell to another; we are trying to clarify a context of meaning. The one cell is *saying something* to the other, not just pushing against it.

Harvard biologist Richard Lewontin once described how you can excise the developing limb bud from an amphibian embryo, shake the cells loose from each other, allow them to reaggregate into a random lump, and then replace the lump in the embryo. A normal leg develops. Somehow the form of the limb as a whole is the ruling factor, redefining the parts according to the larger pattern. Lewontin went on to remark:

> Unlike a machine whose totality is created by the juxtaposition of bits and pieces with different functions and properties, the bits and pieces of

> a developing organism seem to come into existence as a consequence of their spatial position at critical moments in the embryo's development. Such an object is less like a machine than it is like a language whose elements…take unique meaning from their context.[3]

A context of meaning can be thought of in various terms. We can take it, for example, to be the organism's unified *form* in the fullest sense—not only its bodily form (as a flexible, dynamic trajectory of development), but also the "shape" of its pattern of activity, its recognizable and irreducibly qualitative way of being, distinct for every species.[4] Every organic form is a *gesturing*, which is also to say, a kind of *speaking* or an expression of meaning. And we could just as well say that the organism's gesturing manifests the *character* we recognize in the organism as a whole.

Gesture, character, significant form, a tapestry of meaning—these terms all point to the "something more" that, as we found earlier, makes the language of physics and chemistry inadequate to describe the organism. They also typify our way of thinking about beings, as opposed to things. That is, they require a language of directed intention (*respond*, *develop*, *adapt*, *regulate*, and so on); an aesthetically colored language (everything relating to *health* and *disease*, *order* and *disorder*, *rhythm* and *dysrhythmia*, *harmony* and *disharmony*); and a language of wholeness (*unity*, *coordination*, *integration*, *organization*). In fact, just about all the kinds of meaning we express in our words, thought, and activity find their analogue in our descriptions of organisms. Not surprisingly, then, the biologist directly invokes meaning itself in terms such as *message*, *information*, *communication*, and *signal*.

The biologist's reliance upon the *because* of reason—a *because* that resonates so intimately with the meaning of our own lives—is no small thing. It is no small thing, that is, to find ourselves living together with all our fellow creatures in a *community of meaning*. For in the realm of meaning, there can be, finally, only one community; a hermetically sealed compartment of meaning wholly disconnected from all other meaning is an impossibility. If this truth of community hasn't been loudly proclaimed from the research laboratories to the wider public, it is only because biologists have gone on for decades using the language of meaning while remaining content never to *reckon* with it—and even effectively denying it with a contradictory language of mechanism and control. It is past time for the reckoning.

The Inwardness of Beings

Meaning—at least when we are not trying to camouflage it in some narrow mechanical or mathematical notion of information—derives from and expresses a qualitative *inwardness.* It testifies to mind, feeling, volition, consciousness. And because, in our biological descriptions, we refer meaning to organisms, it appears we are ascribing inwardness to these organisms. And so we are. But there are important distinctions to be made.

Meaning need not be thought of solely in terms of our own human consciousness. Everyone accepts that neither the bird building a nest nor the embryo "constructing" a heart is self-consciously realizing its own purposes and meanings. Likewise, the directed nature of cellular processes does not imply conscious, human-like purpose, and, more generally, the meaning I have been referring to need not involve anything like our own conscious awareness.

This is not to suggest, however, that meaning is no longer meaning. Our knowledge of ourselves informs us that the *because* of reason can play out in less than full consciousness. We know that it weaves throughout the psyche, conscious or otherwise, all the way down through subconscious urge and habit to biologically rooted instinct and even to physical reflex.[5] It is not so unexpected, then, to discover meaning-governed activities also at the molecular level, where they manifest as regulation, organization, signaling, responsiveness, and all the rest. Organisms, so far as the biologist has been able to determine, are alive and whole and engaged in activity shaped by relations of meaning—a meaning whose signature is recognizable all the way down.

What is it, after all, that becomes conscious in the human being? All our growing knowledge of our own complex psychosomatic unity suggests that the inwardness at work in the formation and activity of the body, from the molecular level on up, is akin to—not radically other than—what comes to awareness of itself as psyche. The fact that our physical organism so directly and intimately reflects not only our explicit volitional commands but also our inner, meaningful states ("I blushed because I saw a hint of suspicion in his eyes")—while, conversely, our inner life is directly affected by our bodily state, as when we are sick or in pain—leaves little room for a radical separation of psychic meaning from the bodily (molecular) meaning we traced earlier.

You will recall that we have been trying to identify the *being* assumed (whether explicitly or otherwise) by biologists when they describe the organism. This being pursues its life within a context of meaning, and possesses a kind of inwardness that is not sharply separable from human consciousness. Beginning with a molecular-level analysis of the simplest, single-celled organism extant today and proceeding through all the ever more complex creaturely orders, we see no sudden discontinuity in the play of meaning and inwardness—a play that progressively comes to a focus in the individuated centers of consciousness we know as our selves.

If there is an uncomfortable element in all this for many biologists, it arises from the perceived difficulty of reconciling the inwardness of beings with a faith in all the materialist metaphysical baggage that has accumulated around the sciences. This presumably accounts for biologists' shyness in owning up to their own language. But, leaving aside the oddity that biologists seem much more concerned than physicists to preserve a materialist faith, we will now see that the problem posed by living beings in relation to physical science results solely from misunderstanding.

Laws and Causes

The physicist wants laws that are as universal as possible, true of all situations and therefore unable to tell us much about any particular situation—laws, in other words, that are true regardless of meaning and context. So far as a physical law is concerned, once we know it, every subsequent observation merely demonstrates something we already knew: the law will yet again be obeyed. This requires a severe abstraction from the presentational richness of the phenomenal world, which presents us at every moment with something new. Such abstraction shows up in the strong urge toward the mathematization of physical laws.

While the laws usually considered most fundamental remain (at least ideally) valid regardless of context, we can put them most conveniently on view by establishing carefully contrived *closed systems*—systems as immune as possible to outside (contextual) interference. That's because contextual changes tend to obscure the particular law we are after. An apple released from a tree *may* fall straight toward the center of the earth with more or less constant acceleration—but not if I stretch out my hand and grab it, or a sudden gust of wind arises, or it strikes a bird or insect, or there is a meteoric explosion nearby, and so on. Gravity, of course, will be respected in any case, but sometimes we want to see its role displayed without ambiguity or interference—see it as a matter of demonstrable cause and effect and easy measurement. And so, perhaps, we may contrive to drop the apple within a vacuum chamber, a relatively closed system that eliminates air resistance and insects, and demonstrates the mathematical lawfulness of gravity as directly as possible.

This allows us to talk more convincingly about how one thing "makes" another happen: depressing a button on the outside of the chamber releases a lever, which makes the platform drop suddenly, whereupon the apple, under the effect of the earth's gravitational field, accelerates downward. There is a predictable sequence of events here, so that we commonly say one thing or event *causes* the next—or, at least, does so if the release mechanism isn't corroded, an earthquake doesn't upset the apparatus at a crucial moment, air hasn't leaked into the system, there's been no sublimation of gases from the materials inside the chamber, and so on.

Clearly, the "causes" in our demonstration are not laws; they never make things happen with the kind of unvarying certainty we associate with physical law. In fact, a "cause" is nothing anyone has ever managed to define with any adequacy. It's a rather vague, approximate, and anthropomorphic idea, derived from our own experience in "making things happen." Statistician David Salsburg, author of the 2001 book *The Lady Tasting Tea*, states bluntly that "There is, in fact, no such thing as cause and effect. It is a popular chimera, a vague notion that will not withstand the batterings of pure reason."[6]

I can now clear up a certain ambiguity in my earlier discussion of the *because* of physical law, where I might have been taken to imply that gravity "causes" a ball to roll downhill. There are, in fact, various occasions when balls roll uphill, whether due to wind or ocean waves on the beach or some other factor. Gravity doesn't make balls roll downhill, but rather accounts for certain invariant and lawful aspects of their motion, whatever that motion may be. If we want the *because* of physical law to retain the strict, syntactic precision I spoke of, then it should refer only to these invariant, lawful features.

As for what Salsburg calls the "chimera" of causes, popularly conceived, there is no reason we cannot speak of them, if only roughly, in contexts that are more or less stable and closed. They are the basis for what we might refer to as the "cause-and-effect *because*," or the "machine-like *because*," for we try to make our machines (in their standard working contexts) into just such closed, causal systems. And we typically succeed well enough, until rust or a power glitch or the fist of a disaffected user or normal wear and tear brings an end to the desired causal regularity of the system. Presumably nothing ever goes wrong with the physical laws that were operative in the system, but any given causal relations can always be sabotaged by a contextual change.

We can see, then, why physicists are more interested in lawfulness than in identifying causes. They know it is impossible to construct an absolutely closed system with absolutely reliable causes. Any local causal arrangement can be invalidated by a different context (the meteoric explosion), and therefore the arrangement doesn't have the kind of perfectly predictable character that physical laws are often thought to have. The observed "causal" character is neither unqualified nor intrinsic to the given objects and processes in the way that physical laws seem intrinsic to material phenomena.

It will be important to keep in mind these distinct aspects of the physical sciences: on the one hand, precise, invariant relationships—the fundamental laws—implicit in whatever happens; and, on the other hand, the much less precise, never absolute, never infallible notion of a *cause*, which is supposed to tell how one thing makes another happen, that is, how one event, or set of conditions, brings about another event or set of conditions.

Many people, when they speak of the world's "causal regularity," are actually referring to its lawfulness. This conflation of law and cause—this illegitimate bestowal upon *physical causes* of the regularity, predictability, and certainty associated with *physical laws*, as if the causes had the same necessity as the laws—yields a great deal of mistaken thought. Among other things, it lends to any science guilty of it the illusion of vastly greater explanatory power than it in fact possesses. This helps us to understand why so many biologists see a determinate machine where there is in fact a living being; the physical *lawfulness* discoverable in the organism is unthinkingly equated in their minds with a collection of *causal mechanisms.*

In sum: laws do not determine any event at all, but only tell us something about how it will happen: certain invariant relations will be respected. Causes, on the other hand, approximate and ill-defined though they be, can give us a contingent sense for what may reasonably be expected within a temporarily limited and more or less closed system.

Curiously, physicists are much less likely to confuse law and cause than are biologists. I say "curiously" because at least the physicist can achieve, with machines, an approximation of reliable causes. The biologist, as we will now see, is denied even a reasonable approximation.

Beings in Context

All this gives us a further perspective on the animate-inanimate distinction. We have already seen that biology is distinguished from the physical sciences by the free use of the *because* of reason. Now, looking from a slightly different angle, we can consider the issue in terms of law and cause.

No biologist today will deny that fundamental physical laws continue to apply without exception to organisms. But what about causes? We have just now noted that, by means of carefully designed closed systems more or less immune to contextual interference, it is possible to say one thing "causes" another, with due caveats. Machines are such systems. But what happens when the biologist attempts to see the organism in the same mechanistic light, making a closed system of it?

The effort fails miserably. For in biology a changing context does not interfere with some causal truth we are trying to see; contextual transformation is itself the truth we are after. Or, you could say: in the organism as a maker of meaning, *interfering is the whole point.* The ongoing construction and evolution of a context, with its continually modulated causal relationships, is what the biologist is trying to recognize and do justice to. Every creature *lives* by virtue of the dynamic, pattern-shifting play of a governing context, which extends into an open-ended environment. The organism gives expression, at every level of its being, to the unbounded *because* of reason, the tapestry of meaning, the form and character I referred to earlier. It can change its proximal goal from moment to moment, thereby also changing the contextual significance of the details of its life.

Remember that, in a play of meaning, every new element, every new encounter, every new "word" that is expressed may shift the connotation or significance of every other element. The whole purpose of meaningful expression is to add something to what has already been said—to reshape an existing context in light of a further meaning; otherwise, no speaking, no gesturing, would be necessary. A coherently changing context is the very substance of meaning. When a deer is grazing in a meadow, its glimpse of a vaguely canine form in the distance changes the meaning of everything from the flowers and grass the deer was eating to its own internal digestive processes to the expression of its genes. This happens not because the distant form is exerting some strange physical force upon the deer, but because that form becomes part of a now suddenly shifted pattern of meaning.

Or (to focus on the cellular level): when a cell enters into mitosis, just about every detail of its physiology and chemistry takes on an altered meaning in light of the changing context—and similarly when a cell experiences heat shock, oxygen deprivation, or other stress; when it comes into contact with new neighbors; or when it proceeds along a path of embryonic differentiation. The cellular environment, as an evolving context, is continually being *reinterpreted* and *responded* to—is itself a reinterpreting and responding.

Because every local activity of the organism must find its meaningful place within the encompassing activity of a striving, developing, self-transforming whole, there can be no fixed syntax, no mechanical constancy of relations among the parts. Certainly you still can, without self-deception, consider yourself to be identifying causes in the organism. What you are doing is recognizing physical lawfulness in the current context. But it is a context that remains what it was only for a moment. The organism, regarded as a closed system relative to the causes under investigation—the only kind of system in which stable causes can even be defined—is forever abandoning its old state and entering a new one. Therefore no cause can reliably be assumed to remain the same cause over a period of time. When a larger, dynamic intention is reflected in the changing significance of each part, the organism as a whole governs the activities of its parts rather in the way the meaning of an unfolding text or play governs its parts.

Against this backdrop, it's worth taking a moment to listen to biologists puzzling over questions of cause and effect. To keep the following survey brief, we will focus narrowly on certain issues of gene regulation, especially in relation to the organization of the cell nucleus. All of these examples are from the last decade. (There is no need to worry about the technical details; the general sense of the remarks is all that matters here. One note, however: chromatin is the complex of DNA, protein, RNA, and other molecules that constitute chromosomes.)

> • Technological advances are…revealing an unexpectedly extensive network of communication within and between chromosomes. A crucial unresolved issue is the extent to which this organization affects gene function, rather than just reflecting it.[7]
>
> • Together, these results further emphasize the role for RNA polymerase in shaping the chromatin landscape of the genome and point toward the difficulty in disentangling cause and effect in the relationship between chromatin and transcription.[8]
>
> • A longstanding question is whether [cell] replication timing dictates the structure of chromatin or vice versa. Mounting evidence supports a model in which replication timing is both cause and consequence of chromatin structure by providing a means to inherit chromatin states that, in turn, regulate replication timing in the subsequent cell cycle.[9]
>
> • Despite the difficulties in proving cause and effect, these examples convincingly illustrate how chromatin crosstalk can functionally increase the adaptive plasticity of the cell exposed to the changing microenvironment.[10]

- A related unresolved question is whether chromatin loops are the cause or the effect of transcriptional regulation.[11]

- Which genes are the "cause" and which are the "consequence" of plastic development?[12]

- Despite abundant evidence that most kinds of tumor cells carry so-called epigenetic changes, scientists haven't yet worked out exactly whether such glitches are a cause or a consequence of disease.[13]

- The clarification of the cause-and-effect relationship of nuclear organization and the function of the genome represents one of the most important future challenges. Further experiments are needed to determine whether the spatial organization of the nucleus is a consequence of genome organization, chromatin modifications, and DNA-based processes, or whether nuclear architecture is an important determinant of the function of the genome.[14]

One would think that biologists might pause and consider the possibility that the kind of stable causal relationship they've been looking for simply isn't there—the possibility that they've defined their task in misleading terms. Yet when researchers find, for example, that patterns of nuclear organization are implicated in cancer, an almost automatic exhortation follows: "However, it is crucial to determine the extent to which cancer-associated changes in nuclear organization are cause or effect."[15] But is it crucial? Are the actual goings-on in the cell in fact proving so clear-cut? Why do we *need* causes as an addition to lawfulness and meaning? After all, we have no difficulty understanding all the relationships in a meaningful text, even though we cannot say that one part of the meaning *causes* another part.

To Explain or Portray?

The pursuit of causes in biology is something fierce. There is evidently a visceral feeling that without causal mechanisms we have no explanation, and without explanation, no understanding. It is a prejudice so deeply engrained, so resistant to removal, that it has badly distorted the entire field of biology. The billions of dollars poured into molecular research during these past several decades bespeak more than anything else a single-minded quest for causes—a quest that has, by many accounts, been severely frustrated.

It may seem a mere curiosity that over two centuries ago Johann Wolfgang von Goethe, aware that precisely this single-minded desire for causes had already possessed many of his scientific contemporaries, took a stand against it. He declared of his own pioneering morphological research that "its intention is to portray rather than explain."[16] A science whose central task is not to explain, but rather to fill out portraits? At a time when naturalists have become a nearly extinct species and geneticists have found an ideal habitat in front of instrument display panels, not many will be prepared to accept such a prescription for the researcher. And yet, Goethe's stance was extraordinarily prescient.

How, in fact, do we come to understand any context of meaning—a dance, a painting, a novel, a human life, the choreography of a developing embryo? Goethe noted the impossibility of capturing an "inner nature"—say, a person's character—in any kind of direct causal or explanatory way. "But when we draw together his actions, his deeds, a picture of his character will emerge." That is certainly how we try to understand each other—and we, too, are organisms. I daresay that, insofar as several decades of expensive cancer research have brought progress, it is not so much because this or that causal mechanism has been discovered (such mechanisms are announced by the dozens every month in scientific journals) as because all the false starts, dead ends, and mutually contradictory "mechanisms" have bit by bit been revealing (to those looking for it) a qualitative picture—a personality, so to speak—of the disease.

Such knowledge is not impotent. If I familiarize myself with the distinctive way of being of a blue jay, I may not be able to predict exactly what it will do or project its flight as a Newtonian trajectory. But my knowledge is nevertheless real. I will, in appropriate circumstances, be able to say, "Yes, that is just like a blue jay," or "No, that is not at all what one would expect of a blue jay in this situation. There is something wrong, or something missing from the picture." With such knowledge I can learn to interact meaningfully with the bird even though I cannot mechanistically predict its behavior. In developing a qualitative portrait, we aim less at exact prediction and control than at understanding and the potentials for working with nature.[17]

The main question about a portrait is how full, how detailed, how multifaceted a picture we gain. The supposed causes, of course—when properly contextualized and shorn of their strict causal aura—help us to build this picture. There is neither any end to our picture-building, nor an inherent limit to how far we can carry it. And biologists surely *are* carrying it further, even when they think they are fingering explanatory causes.

In other words, these remarks point more toward what is the (partly unrecognized) reality of biological research than toward some utterly new strategy. All the meanings we have seen in biological language are, after all, pervasive, testifying eloquently to the efforts to portray health and sickness within an overall organismal context of coordination, regulation, globally directed communication, and so on—this despite the simultaneous and contradictory appeal to causes neatly isolated from the whole.

The Ultimate Cause, of course, was supposed to be the genomic sequence, or DNA. But Florida State University biologist David Houle and his colleagues remind us that, for the most part, phenotypes (observable traits—partial portraits, if you will) "continue to be the most powerful predictors of important biological outcomes, such as fitness, disease and mortality. Although analyses of genomic data have been successful at uncovering biological phenomena, they are—in most cases—supplementing rather than supplanting phenotypic information."[18] And what is true of prediction applies just as well to causal analyses and treatment—a fact that's easy to lose sight of amid all the wonders of modern molecular technologies and all the talk of treatable "causes." The International HapMap Consortium (a successor to the Human Genome Project) summarizes the situation neatly in the lead sentence of a report in *Nature*: "Despite the ever-accelerating pace of biomedical research, the root causes of common human diseases remain largely unknown, preventative measures are generally inadequate, and available treatments are seldom curative."[19] And William Bains, chief scientific officer at Amedis Pharmaceuticals in the United Kingdom, wrote upon the completion of the Human Genome Project:

> The chances that genome properties can be used to predict organismal ones is remote. Genomics and its daughter technologies are valuable instruments in the analysis of cells and tissues. They provide means of exploring biological processes and phenomena. However…they will not often address most human needs.[20]

Low-level analyses versus portrayal of the whole: it's not an either-or matter. Because we're dealing with meaning, the similarity to the understanding of texts is not accidental: analyses of individual words and their possibilities of meaning can be essential; without a knowledge of the words, we can hardly grasp the whole. But at the same time, it is only the meaning of the whole that gives the individual words their full and proper significance. This is the truth that has for so long been ignored within biology.

Can We Explain the Form of Organisms?

The challenge and opportunity of portrayal deserves concrete illustration. Consider the effort, common nowadays, to explain an organism's form by referring to genetic switching networks. Developmental biologist Sean Carroll presents beautiful pictures of patterns in the early fly embryo—patterns that prefigure and map directly to the later arrangement of larval segments. Each element in a pattern corresponds to the distribution of certain molecules (made visible and colorful with special dyes), which in turn can be at least roughly correlated with the activity of a particular collection of genes. He suggests that a complex arrangement of genetic switches *explains* the molecular patterns and therefore also explains the eventual form of the organisms.[21]

But we now know from the vast literature on gene regulation (oddly, Carroll does not even mention epigenetics in his book) that those supposed switching networks are in fact penetrated and influenced by virtually everything going on in the cell. By the time we get very far in tracing the relevant interactions through the organism, we realize that we're witnessing, at the molecular level, the playing out of the very form, the patterns, that we hoped to explain, but at another level of description.[22] If we really did need explanatory mechanisms, then we'd still be left with a version of our original task: to explain what governs, controls, or regulates the complex, interacting molecular patterns that we find as such vivid, directed, perfectly shaped presentiments of the developing morphology.

Carroll repeatedly talks about how various genes "sculpt" a fly's wings and various anatomical structures of other animals, adding that the action of these genes "in organizing, subdividing, and specifying and sculpting parts of the embryo becomes clear when visualized." But it's obvious enough that a section of a DNA molecule does not "sculpt" anything. In fact, the research emphasis today is in the reverse direction: how proteins and the overall activity of the cell sculpt the genes and chromosomes. Biologists speak of "DNA-sculpting proteins," of histone modifications that "sculpt" chromatin (the substance of chromosomes), and of the sculpting of DNA into functional domains and loops. In general, studies on the three-dimensional organization of chromosomes in the nucleus are all the rage, and it is widely recognized that this organization reflects how the organism is making use of its genes. In trying to understand gene expression, biologists "are looking for answers" by studying how the chromosome "folds, moves, and communicates."[23]

As this last remark indicates, we're not talking about a static sculpture. In a 2003 article in *Nature* entitled "Beyond the Double Helix," Helen Pearson interviewed many geneticists in order to assemble the emerging picture of DNA. One research group, she reported, has shown the molecule "to gyrate like a demonic dancer." Others point out how chromosomes "form fleeting liaisons with proteins, jiggle around impatiently, and shoot out exploratory arms." Phrases such as "endless acrobatics," "subcellular waltz," and "twirls in time and space" are strewn through the article. "The word 'static' is disappearing from our vocabulary," remarks Tom Misteli of the National Cancer Institute.[24] Countless extra-chromosomal factors contribute to this dynamic performance.

The activity of individual genes reflects the choreography of chromosomes, which reflects the larger choreography of the nucleus, which reflects the choreography of the cell and organism as a whole. Who, then, is sculpting whom?

It's not that identifying a so-called gene "switch"—or calculating kinetic energies or measuring mechanical stresses on macromolecules—gives us no understanding. Of course such insights are important. But they become biological insights, as opposed to physical and chemical ones, only insofar as they find their place within the living, metamorphosing form of the organism. They do not explain the form. If anything, we should say that the form explains the physical interactions—in the sense that it gives us an understanding of their pattern, their shape, their direction and place within a functional whole, none of which can be deduced from physical transactions as such. We can *observe* the patterns by tracing the physical interactions, but what those patterns will turn out to be can never be arrived at merely by working out the implications of the physical laws and substances.

This same scenario is playing out in other biological investigations. One of the most dramatic examples centers on the circadian rhythms that figure so prominently in human life. Biologists, of course, set out to identify the "clock mechanism" that was presumed to "control" these rhythms, and, yes, they found a rhythmical feedback loop involving genes and transcription factors in a certain area of the brain that seemed the perfect candidate. However, ongoing research has revealed distinct "clocks" in different mammalian organs and tissues, and indeed in every cell. These "clocks" are interwoven with each other and, it now seems, with virtually all aspects of the organism's physiology—metabolism, reproduction, cell growth and differentiation, immune responses, central nervous system functions, and on and on.

In each of these areas the quest for causes and master controllers leads to the usual perplexity about who's doing what to whom. For example: "Although metabolism is thought to be primarily downstream of the cellular clock, numerous studies provide evidence that metabolic cycles can operate independently from or even influence circadian rhythms."[25] At the molecular level, one research team remarks that the enzymatic function of a certain clock protein "may be controlled by changing cell energy levels, or conversely, could regulate them."[26] In general, "It seems that connections between the circadian clock and most (if not all) physiological processes are bidirectional."[27]

What we're gaining from all this research is a wonderful portrait of the organism as a rhythmical being—a being in time. Investigators have not found controlling mechanisms that single-handedly establish or govern the circadian rhythms of the organism, but rather are discovering how those rhythms come to expression at every level and in every precinct of the organism—perhaps more centrally here and more peripherally there, but altogether in a single, organism-wide harmony. There is no sensible way, as a scientist, to speak of particular mechanisms that *explain* this harmony. Instead, every isolated "mechanism" is found to be a reflection of the harmony, and we thereby gain further, detailed understanding of how the organism functions as a being in time.

Finally, if there was any place where biologists expected a causal explanation of the organism to emerge clearly, it was in the study of *Caenorhabditis elegans*, a one-millimeter-long, transparent roundworm whose private molecular and cellular affairs may have been more exhaustively exposed than those of any other organism. The adult hermaphrodite has exactly 959 cells, each precisely identified as to origin and type; for example, 302 cells belong to the nervous system. The developmental fate of every somatic cell, from egg to adult, had already been mapped out by 1980, but this mapping and the associated molecular studies did not produce the expected explanations. Sydney Brenner—who received a 2002 Nobel prize for his work on *C. elegans*—acknowledged that development "is not a neat, sequential process.... It's everything going on at the same time." Even regarding the carefully mapped cell lineages of this "simple" roundworm, "there is hardly a shorter way of giving a rule for what goes on than just describing what there is." In other words, the only "rule" for the development of this worm is the developmental description of it. When critics suggested he had not really come to an understanding of the worm, but had "only" described it, Brenner responded, "I'm not sure that there necessarily is anything more to understand than what it is."[28]

While there is good reason to think that Brenner never took his own words with full seriousness—and biologists in general still have not gotten the message these many years later—Goethe would certainly have seen truth in Brenner's remark. The difficulties of causal explanation encountered by the *C. elegans* researchers were not accidental. You can't explain an organism of meaning, and you don't need to. You need only allow it, like any meaningful text, to speak ever more vividly and clearly, in ever greater detail. The separate processes do not make tidy explanations because they are not really separate and are not just doing one thing; they are harmonizing with everything else that is going on in the organism. We gain understanding when we learn to recognize this harmony in every aspect of the organism. Various analyses can play a crucial role in bringing clarity to our understanding. But the full picture takes shape only when the analytical threads are woven back into the larger fabric of meaning.

We have an increasing appreciation today of the importance of organismal context, and of the organism's plasticity, and of its dynamism, and of the complexity of its interweaving processes, and of the causal ambiguity of our explanations. For a mindset fixated upon causal mechanisms, all these factors might be viewed as unwelcome complications—detours on the way toward *real* understanding. But do they really make our descriptions and explanations *less* revelatory of the organism than what we had before, when gene-mechanisms were supposed to provide a "blueprint" or "instruction set" for the organism as a whole? Shouldn't we expect that the processes we cannot neatly tie down or capture in mechanisms are precisely what bring the organism *alive* for us?

Fear of Vitalism

The organism, we have seen, is continually expressing the *because* of reason. Possessed of a certain inwardness, it is a maker of meaning, a fact most immediately presented to us in our own lives as self-conscious beings, but further evident all the way down to the eloquent and concerted molecular interactions of every living cell. We recognize meaning in the vocalizations, body language, and gestures of animals; in the qualities that make the oak tree a recognizable presence, consistently expressing its own *character*, distinct from a willow tree; and in the active, directed striving for self-realization in all organisms—a striving that enables us to speak reasonably of their health and disease, wholeness and injury.

And yet, in a baffling show of tolerance for contradiction within science, an entrenched metaphysical dogma assures us that the universe in which these creatures of meaning exist is a universe inherently without meaning, idea, or thought.

The truth of the matter may simply be so close to us—so fundamental and so intimately a part of our nature as understanding beings—that we cannot readily step back and see it. I mean the truth that any understanding of the world, animate or inanimate, must be an *understanding*—which is to say, it requires a *conceptual* grasp of things. Whatever is incommensurable with thought and idea will never be contemplated in thought and idea, and therefore will never enter into science. The world we know will always and only be a world in whose inwardness we can participate inwardly—a world whose being can take form as a content of consciousness. Without a truth of things that can at the same time be a truth of word and thought, we could have no scientific conversations or textbooks—no science at all.

The physicist has *not*, as so often claimed, succeeded in presenting us with a world of pure objectivity or outwardness—a "disenchanted" or "disensouled" world. He has only tried to restrict the enchantment to the sphere of mathematics. But mathematical relations or concepts are still ideas, not things, and the universe is, if nothing else, startlingly enchanted by these ideas. The question "Who is the enchantress?" may be beyond our ken at this time, but this does not remove the facts that provoke the question. Oddly, physicists seem far ahead of biologists in their occasional and explicit openness to these facts. When an astrophysicist penned an essay in *Nature* entitled "The Mental Universe," it produced hardly a murmur of surprise from his peers.[29]

None of this is to abolish the qualitative distinction between the animate and inanimate worlds. To say that the world is an embodiment of meaning and idea is not to say that all things have the same meaning or that meaning manifests itself in the same way in all things. We saw above that coherently evolving *contexts* of meaning are the very language of the organic realm. Organisms cannot be fully elucidated in terms of the definitive lawfulness so satisfactory to the physicist—a lawfulness lending itself to the application of mathematics and other reduced "skeletons" of language. This is a great difference. If we live in a thought-soaked world—one that includes the amoeba as well as the stone, celestial fires as well as earth-bound winds, human beings as well as human-devised machines—then it is the task of the scientist to find the appropriate sort of language for bringing to light the phenomena of each different realm.

But this entire discussion of ideas and meaning *in the world* brings us face to face with a haunting specter we need to exorcise once for all: the specter of vitalism. The accusation of vitalism seems inevitably to arise whenever someone points to the being of the organism as a maker of meaning. This is owing to a legacy of dualism that makes it almost impossible for people today to imagine idea, meaning, and thought as anything other than ghostly epiphenomena within human skulls. So the suggestion that ideas and meaning are "out there" in the world of cells and organisms immediately provokes the assumption that one is really talking about some special sort of physical causation rather than about a content of thought intrinsic to organic phenomena. That is, ideas and meanings are taken to imply a vital force or energy or substance somehow distinct from the forces, energies, and substances referenced in our formulations of physical law. Such an entity or power would indeed be a spectral addition to the world—an addition for which no one has ever managed to identify a physical basis.

But ideas, meanings, and thoughts are not material things, and they are not forces. Nor need they be to have their place in the world. After all, when we discover ideal mathematical relationships "governing" phenomena, we do not worry about how mathematical concepts can knock billiard balls around. If we did, we would have made our equations into occult or vital causes. But instead we simply recognize that, whatever else we might say about them, physical processes exhibit a conceptual or thought-like character. And so, too: the meanings that give expression to the *because* of reason do not knock biomolecules around, but—like mathematical relations—are discovered in the patterns we see. The thought-relations we discover in the world, whether in the mathematical demonstrations of the physicist or the various living forms of the biologist, need to be genuinely and faithfully and reproducibly observed, but must not be turned into mystical forces.

The scientist observes meanings at play in organisms, and necessarily appeals to them in biological explanation. Anyone who construes this appeal as conjuring unacceptable vital forces needs not only to torch almost the entire biological literature, reconstructing it upon some new and as yet unknown basis; he also puts himself in an untenable position regarding the human being. For at least some of what we do, we do because we consciously think and intend it. If invoking this *because* of reason—this play of meaning and idea—in the explanation of human behavior is to rely on vital forces, then virtually everyone (in daily life, if not within a cocoon of theory) is a vitalist. If, on the other hand, we grant meaning to the human being without trying to make this meaning an expression of vital forces, then we can hardly voice the charge of "vitalism" when we observe meaningful activity in less conscious forms—for example, in the activity of cells and lower organisms.

So, no, we don't need vital forces. If the organism as an expression of meaning requires us to recognize a different sort of order from that of inanimate nature, science offers no presumption against this. Our knowledge of some thought-relations in the world—for example, those of mathematized physical law—does not tell us what other thought-relations we might discover in various domains. The mathematical order, however, does tell us that there must *be* other principles of order. For mathematics alone does not give us any things or phenomena at all; numbers are not things. Whatever the things may be to which our mathematical formulations refer, they either have a qualitative character that we can consciously apprehend in a conceptually ordered way, or they must remain unknown and outside our science. And that qualitative conceptual ordering cannot be predicted from the mathematics. Rather, the qualitative order is the fuller reality that determines whatever we abstract from it, including mathematical relationships.

Who can tell us in advance what forms of order we may discover in this more-than-numerical world? If, in organisms, we observe principles of coordination through which physical laws are not only fully respected but also caught up in higher-order, integrated, harmonious, and self-assertive forms—well, then, that's what we observe. The ideas expressed in that coordination and integration may be more saturated and resonant than the concepts of the physicist, but they are no more our arbitrary invention than is the mathematical harmony of planetary motions.

We may not yet understand how the coordination comes about—how living beings bring such meaningful, ideal relations to manifestation in the world—but this is no obstacle to scientific acknowledgment of the observed relationships. After all, our ignorance about how gravity works or what energy or space or time or matter *is* does not prevent us from teasing out certain observable, lawful relationships. Disciplined observation should be our guide to the various sorts of order displayed in the world. And while observation shows us an uninterrupted continuity of physical law when an organism dies, it also reveals a striking discontinuity, marked by a loss of the overarching coordination and the governing meaning through which a living form had been sustained. The astonishing fact that scientists of life pay very little attention to the significance of this moment of transition in no way detracts from its significance.

I do not at all wish to dismiss as unimportant the question so many will feel to be urgent: Who, after all, "speaks" or gives expression to the meaning we find so clearly displayed in an organism's life? How are we to understand the substantive nature of the beings with whom we share the earth—if, indeed, "substantive nature" is the right phrase? But this is a large issue requiring separate treatment. Given the metaphysical commitments so thoroughly distorting biology today, the first task is to make it at least possible for such questions to be asked. Fortunately, this has required only that we look unflinchingly and without the usual prejudice at what biologists themselves have been discovering.

Biology—More Fundamental than Physics?

A final word about the relation between physics and biology. We have seen that, in the organism, the observed thought-relations have a much thicker texture of meaning than in the physical sciences. The mathematically stated laws toward which those sciences so often strive with at least some success represent thought stripped down to the purest abstraction—to a kind of bare syntax of quantity and logic—whereas the language we see spoken in the organism is much more like a contextualized natural language, semantically rich and qualitative.

While there are real differences here, there are also matters of choice. Physicists have chosen to pull back from the actual phenomena they are confronted with, viewing them as far as possible through the lens of a language blind to those qualitative, phenomenal aspects of the world where we could expect to trace any sort of a meaningful *because*. The kind of world they describe reflects in part the restrictions they impose upon their looking.

So it is that they aim to describe the world of light and color in terms of colorless "waves" and "particles," or mere statistical non-representations—that is, in a way that makes as much (or as little) sense for someone without sight as for those with eyes to see; and they try to describe a world of sound that is indifferent to the presence of hearing ears. In general, they tell us what the world would be like if it were not *like* anything at all—certainly not like anything we can know through our senses, and therefore not like anything we can describe or even imagine. It is no wonder that, at its purest, physics tends to depart from the phenomenal world into abstract and statistical formulations, while physicists enter into debates about the nature of reality that might make a medieval metaphysician blush.

These choices of the physicist are certainly productive so far as our powers of manipulation are concerned. The single-minded focus on general laws we can recognize in the world enables us to assemble the parts of a machine so as to put those laws to work for us in effective "causal systems." Indeed, the fact that science *works* in this sense is often taken to be its chief glory. Certainly it has transformed civilization and given us many things we would rather not do without. But an ability to manipulate things does not imply that we have exhausted the potentials for understanding what we are manipulating. Perhaps it is hardly a beginning. Just as you can drive a car without a clue about how the motor works, so, too, you can "know" how the motor works without a clue about the true nature of forces or energies or even laws.

Those who would like not only to reengineer but also to understand the world have every right to ask: If the inorganic world readily accessible to our perception and theorizing is a world partly characterizable (unlike the living aspects of the organism) by ideas reduced toward a kind of grammar, what is the fuller "speech" implied by the presence of this grammar—the speech of qualitative phenomena from which alone such a grammar could be abstracted? What would we find if we looked where the physicist disdains to look—if we attempted to penetrate physical phenomena with a profound qualitative awareness of the sort that Galileo had already foresworn and the biologist cannot avoid?

To suggest that the world may be a bearer of meaning far beyond what the physicist is currently willing to investigate is not to contend that a rock can be placed on the same scale as an amoeba. It is only to point to the profound darkness of substance itself, in both rock and amoeba, and to ask what quickening mystery may be hidden within it, capable of producing the brilliant kaleidoscope of perceptible qualities we call "the world"—and, indeed, capable of producing living things. This hidden potential of the world's substance must be at least as great as the things it brings to realization.

Alluding to the void left by the physicist's withdrawal from phenomena into mathematical law, Stephen Hawking once asked: "What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science…cannot answer."[30] Whatever life it is that breathes fire into the equations of the physicist, it has retreated far enough behind the physical phenomena, as we routinely perceive and theorize about them, to leave us substantially in darkness. My own suggestion, unsupported here, is that we will have to gain a qualitative science and penetrate much more deeply into the mystery of the physical world before we will be able to see how mathematically reduced physical laws are the mere syntactic skeletons remaining after we have abstracted away the much more richly expressive meaning profoundly present in all phenomena. Surely our immediate experience of oceans and stars, mountains and rivers says nothing to discourage such a thought. The aesthetic and even moral character of this experience bespeaks a significance no less real for all our concerted ignoring of it as scientists.

The depths of physical reality are, of course, as hidden from us in the living organism as they are in the rest of the physical world. But in the organism we encounter something further: reason and meaning come to much more "visible" and insistent manifestation, narrating the stories of living beings—stories that, evoking as they do the intentional and meaningful patterns of our own lives, are more accessible to us than whatever speaks to us now through the qualities of inorganic substance. It is ironic that the organism has been regarded as a more difficult challenge for science than the world of physics. The truth is that the organism is much closer to us—we are, after all, organisms ourselves—and it offers many informed, articulate responses to our inquiries. We can apprehend it with a richness and depth of comprehension far exceeding the admirable mathematical comprehension of the physicist.

If the world is indeed intelligible—if it speaks meaningfully, as must be assumed by every scientist who tries to capture that meaning in revelatory words and ideas—then the place where we find it speaking most fully and explicitly is presumably the place where we will find its fundamental truths most fully declared. And that is in the living organism.

The "difficulty" of the organism is really just the difficulty of reducing it to mere physics and chemistry. Yes, very difficult indeed—but that's because the organism is alive, as we are alive, and because every biologist instinctively understands this life as offering more than lessons in physics and chemistry. As for the "nonliving" world: we imagine it is simpler to understand only because we are bewitched by the precision and predictability of the physical laws we find implicit in things—things of whose nature we know almost nothing.

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