In Context

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The Newsletter of **The Nature Institute**

#30

Dear Friends,

There is something about November in the northern hemisphere that evokes quiet awe. It's a time of letting go, of the old drying up and falling away, of preparation for winter. The old year is dying. Yet this dying, as so many have observed, paradoxically refreshes life and nourishes its continuity.

In the plant world we see a frequent pattern: seeds become mature enough for release even as the current year's growth dies back. But death and decay will enrich and sustain the living soil, increasing the soil's capacity to support the seeds' own coming metamorphosis and to feed the living, hidden roots of perennials. This dying back and decomposition fit inside—not outside—the larger frame of life. It is a transformation that creates both space and actual nourishment for next year's abundant living.

Something similar occurs in human lives, when the work of our predecessors enriches our own. And so we are glad to share with you, in this issue, an excerpt from a 1930 book by E. S. Russell. A Scottish marine biologist, Russell strenuously resisted the "abstract and schematic account" of life that was seizing hold of biology in his day. He was convinced that "in the living thing there are in actuality no separate parts, no separate processes, for no part can be adequately characterized save in terms of its relations to the whole." He wanted to deal concretely with "the whole cycle that is the life of the individual" organism, and to grasp its indissoluble links with previous life cycles.

We also bring you the story of a remarkable organism that can repair a genome broken into hundreds of fragments. Its self-restoring powers, while distinctive, also testify to a general truth: the genome, far from being the decisive maker of organisms, is a resource that organisms employ for their own ends.

In our news about The Nature Institute, we include two new books for good reading on the chilly nights ahead. *Leave No Child Inside,* published by Orion magazine, includes a provocative chapter by Steve. And Craig's *Thinking Like a Plant: A Living Science for Life* is now available from Lindisfarne Books. It's a guide for developing a radical new way of learning from and interacting with the natural world. Both in living and dying, plants reveal lessons for more dynamic, flexible, and fruitful ways of thinking. We hope you enjoy this issue!

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Copies of *In Context* are free while the supply lasts. Past issues are posted on the Institute website. Our *NetFuture* newsletter is available at: http://netfuture.org.

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Shattering the Genome

Stephen L. Talbott

The following is a slight revision of one of the recent articles in a growing collection of news updates and commentaries that are part of our "Toward a Biology Worthy of Life" project. This article and all others in the collection are available at RediscoveringLife.org.

A dose of ionizing radiation equal to 10 grays (a measure of absorbed radiation) is lethal to the human body. Most bacteria cannot survive 200 grays. But then there is the bacterium known as *Deinococcus radiodurans*: it can endure over 17,000 grays and do quite well, thank you. Never mind that its genome is thoroughly shattered by the assault.

Here's what happens. Ionizing radiation can damage DNA in various ways, perhaps worst of all by causing double-strand breaks. These are breaks across both strands of the DNA double helix. The familiar bacterium, *E. coli,* not at all untypically, dies when it suffers about four double-strand breaks per each of its four-to-eight circular DNA molecules. *Deinococcus radiodurans,* by contrast, can survive over a thousand double-strand breaks. This means that it continues life after its genome is broken into hundreds of small fragments. It does so by proceeding to put its genome back together again when living conditions improve — a daunting task, to say the least.

Deinococcus radiodurans is one of a small class of single-celled organisms with extreme radiation tolerance. Actually, it tolerates various other extreme conditions as well — some of which, such as dessication, likewise reduce its DNA to genomic shards. It can, for example, survive in a waterless desert for years. When moistened again — perhaps after winds have lifted it in a cloud of dust from the Sahara, high into the atmosphere (where it is exposed to damaging ultraviolet radiation 100 to 1000 times that on earth's surface), and across the Atlantic ocean to the South American jungles. *D. radiodurans* can be found on Antarctic ice, on dry frozen marble, and in the farthest depths of the sea.

Biologists have been intrigued by this peculiar survivor (along with some of its kin) for several decades, and of late they have clarified its story considerably. A central feature of that story is striking, because it points toward a truth about organisms in general, not merely those with extreme survival capabilities. The key finding is this: damage to DNA is not, in the most direct sense, what proves lethal about radiation. The primary issue, instead, is damage to proteins. As long as its proteins remain functional, a cell can reassemble even a badly fractured genome; but with damaged proteins, a cell is done for, with or without a working genome.

The secret of *D. radiodurans* lies not in an especially stable genome, and not even in highly original proteins for DNA break repair. Rather, the bacterium employs a number of strategies for preserving its rather commonplace "proteome", or total supply of proteins. These strategies include (1) preventing the oxidative damage that results from radiation, a goal it achieves in good part by means of an especially rich supply of antioxidants; (2) eliminating, before they can cause mischief, any proteins that do get damaged, while recyling their constituents; (3) scavenging amino acids and peptides (protein components) from the local environment, a capability that, together with the recycling, (4) supports new synthesis of any proteins that need replenishing.

The proteome thus preserved is then able to go about the task of reconstructing a shattered genome — a task whose complexity at the molecular level is stunning, but one that nevertheless goes on in the cells of all organisms. What distinguishes *D. radiodurans* is its ability to carry out this task to an exceptional degree by maintaining its store of proteins intact under extreme duress.

In sum, according to Anita Krisko and Miroslav Radman, researchers at the Mediterranean Institute for Life Sciences who have been studying *D. radiodurans,* "biological responses to genomic insults depend primarily on the integrity of the proteome ... This conclusion is the consequence of the fact that dedicated proteins repair DNA, and not vice versa." Moreover, "this paradigm is fundamental in its obviousness (no living cell can function correctly with an oxidized proteome) and, if it is true, must be universal, that is, hold also for human cells."

All this says something powerful about the longstanding genocentric (gene-centered) bias of biologists. Krisko and Radman delicately hint at the issue when they write in their recent paper:

> The science of molecular biology was dominated by the notion of information, its storage, transmission, and

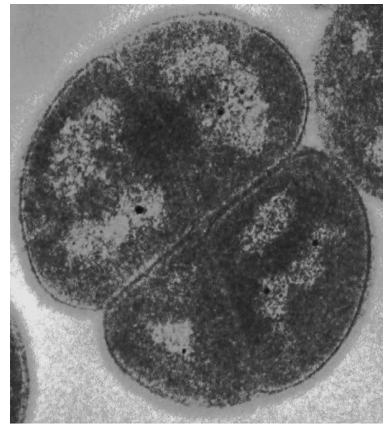
evolution as encrypted in the nucleotide sequence of nucleic acids [constituting DNA and RNA]. But the biological information is relevant to life only to the extent of its translation into useful biological functions performed, directly or indirectly, by proteins ...

This truth, as they also point out, applies to our understanding of cancer and its treatment, which has long been focused on DNA abnormalities. But instead, "an effective cancer therapy by tumor cell killing should target the proteome, or both the proteome and genome, rather than the genome alone."

It was always a strange thing when biologists, attempting to penetrate the thickly matted tapestry of cellular activity at one point or another and disentangle the threads for analysis, decided that one type of element — the gene or DNA sequence — was the place where all the activity logically begins and from where it is controlled. There is in fact no starting place and no part acting as controller, and the very attempt to think in such terms while keeping a picture of cellular behavior in mind immediately brings one up against absurdity. *D. radiodurans* no more shows proteins to be the "controlling" elements than it does DNA. There is an infinite range of ways a cell can shape its thoroughly interwoven processes, and while any given organism may bring one aspect or another to the fore in a particular context, the finely differentiated whole remains integral and irreducible.

If there was one reason for imagining DNA to be the desired starting point, it was the idea that DNA carried the "controlling information" or "computational program" for directing everything else. But this never made any sense. Among other things, it glorified a linear string of statically encoded *information* while ignoring the much more profoundly informed *performances* we observe in the behavior, for example, of those many molecules that coordinate and collaborate in transcribing DNA into RNA — or, for that matter, in repairing damaged DNA.

The molecular complexes carrying out these processes are not simply bumping into each other and chemically reacting in fixed and statistically predictable ways, like the contents of familiar test-tube solutions. Rather, they have intricate tasks to carry out — tasks requiring elaborate sequences of well-timed interactions. Even when these processes have been characterized in some detail, countless bright but befuddled students have twisted their imaginations into knots while trying to picture the actual textbook sequence of events in a coherent manner. This in itself testifies to the depth of directed wisdom at work in those molecular dramas.



Transmission electron micrograph of *Deinococcus radiodurans*. The bacteria typically join together in tetrads.

Photo from the laboratory of Michael Daly, Uniformed Services University, Bethesda, MD.

The work on *D. radiodurans* can remind us that the activity of the organism always reflects something like what we can only refer to metaphorically as a "sense of the whole." The coordinated elements coming to bear upon any particular part seem to "know" how that part is to be related to its larger context. And this work also makes obvious the falsehood in all references to DNA as if it embodied a computer-like program. Arbitrarily break a large program into a handful of separate pieces (let alone a thousand of them), and you face the certainty of its total collapse. Yet every organism deals routinely with a certain number of such disruptions to its genome.

The information we conceive as "encoded" in DNA is a bland reduction of the living intelligence at work in cellular *processes*. It is (to employ a rough analogy) as if we elevated a book of words, phrases, definitions, and grammatical guidelines to a pinnacle high above *Moby Dick* or *Faust* or *War and Peace,* worshipping the former as "information" while ignoring the kind of informed and meaningful activity through which mere words and phrases can be woven into soul-stirring tales.

A phrase-book or dictionary can be an essential resource, but it is the organism (*Deinococcus radiodurans* in the case we have been considering) that uses the dictionary to weave its own story — and even reconstructs the dictionary when the pages fall into a disorganized heap on the floor.

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Rebirth of the Type

Notes on A Recent Paper by Mark Riegner

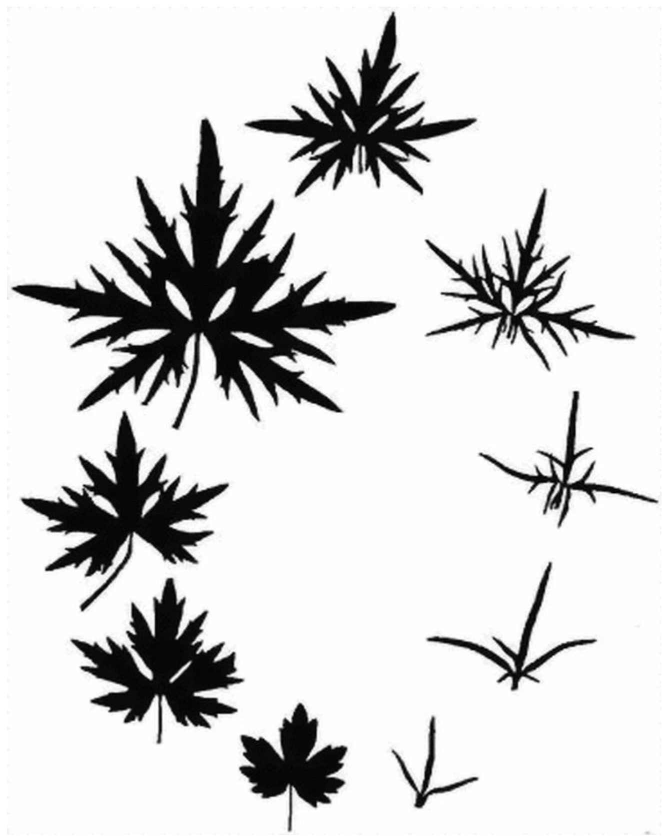
Typological thinking—for example, the idea that in each species we see an essential nature (*type or archetype*)—went out of style with the rise of evolutionary biology and Darwinism. If organisms, as Darwin's work suggested, go through more or less continuous change, with new species arising out of old ones, how could any species be thought to possess a fixed, given nature? Where, along the trajectory of change, would we find that nature?

As it happens, however, there is reason to think that the idea of the organismal *type* may be on the verge of renewal. And one sign of that renewal is the recent appearance of a paper by Mark Riegner in the journal, *Studies in History and Philosophy of Biological and Biomedical Sciences.* Riegner, who teaches in the Environmental Studies Program at Prescott College in Arizona, entitled his paper, "Ancestor of the New Archetypal Biology: Goethe's Dynamic typology as a Model for Contemporary Evolutionary Developmental Biology." The epigraph he chose for the paper is taken from Goethe:

> Form is a moving, a becoming, a passing thing. The doctrine of forms is the doctrine of transformation. The doctrine of metamorphosis is the key to all signs of nature. (Quoted in Richards 2002, p. 454)

Goethe died in 1832, well before the publication of Darwin's *Origin of Species* in 1859. His "doctrine of metamorphosis" was not conceived in the sense of Darwin's evolving species, but rather was his way of looking at the patterns of nature he could see in his own day. That doctrine, however, lends itself well to evolutionary thinking, and it is, according to Riegner, also key to the reconciliation of typology with evolution.

The type rejected by biologists, being a static essence, could not survive the onset of evolutionary thinking. Goethe's *type*, by contrast, was dynamic. Perhaps the most common way to illustrate it is with the sequence of leaves successively growing along the stem of an herbaceous plant, as shown in the accompanying figure. (The figure should be read from the lower left around the circle to the lower right, which is the order of leaves upward along the stem of a field buttercup (*Ranunculus acris*). No leaf will be exactly repeated on the stem of any two plants, and the leaves on the stem of a single plant differ greatly. Yet we can recognize a *movement* of a particular character in the sequence. Its character is objective; if one leaf is omitted from such a series and then handed to us later, we would be able to identify in exactly which gap it belonged. And if we were handed a leaf from a completely different kind of plant, we would probably be able to notice its disso-



nance with the kind of movement we see in the buttercup sequence. This recognizable movement, then, is one manifestation of what we might call the *type* of the buttercup.

The leaf series illustration may be very familiar to some of our readers, but is probably something of a novelty for the readership of the journal where Riegner's article appeared. Riegner uses it, along with other material, to drive home the relevance of Goethe's typological thinking for contemporary biology. Stated very briefly, here are some of the issues he addresses:

• Transformation, metamorphosis, and movement are themes inviting a consideration of the individual organism's development ("ontogeny"). Riegner quotes Goethe to the effect that "Reason takes pleasure in development; practical understanding tries to hold things fast so that it can use them." As it happens, the emphasis on development has come front and center in today's biological thinking. Many believe that attention to development has been a critical missing element in evolutionary theory for the past century. Where embryologists and morphologists have interested themselves in the *explanation of the origin of form,* writes Riegner, "Darwin's goal was the *explanation of change,* with little interest in understanding how form arises." But now, especially in the field known as "evo-devo" (evolutionary developmental biology), the reality of the organism's development is being brought into connection with evolution. Many believe that we can understand evolutionary change only as a transformation of the individual organism's developmental process.

• The plasticity and dynamism of the Goethean *type* are well suited to the relationships we see between groups of organisms. For example, when we look at the cat family (Felidae), we recognize in each of the thirty seven living species "the lawful integration of organic features that constitute the expression of the dynamic type ... As disparate as are a tiger, a mountain lion, and an ocelot, for example, they are but variations on a theme, the *One* form expressed in the many." And that form in turn can be seen as one of many forms in the group, Carnivora (wolves, badgers, bears, and so on), which has its own recognizable *type*, of which cats are a *subtype*. Similarly again with the Carnivora in relation to the still larger group, Mammalia … until one reaches the Goethean notion of the *ur*-animal, or single type that comes to expression in all animal forms. Reverting to the plant leaf series: just as the unity of the series along the stem of one plant is just one manifestation of the larger unity of the species (a unity that comes to expression differently in different habitats), so, too, the species is one dynamic manifestation of a broader *type*—and the nesting of *subtypes* within higher *types* can in this way continue indefinitely.

• The dynamic, interpenetrating relationships among Goethean *types* also helps to make sense of what usually goes under the heading, "convergent evolution." The so-called "camera eye" common to cephalopods (such as the octopus) and vertebrates (including mammals) is often cited as one of the more dramatic examples of convergent evolution. This eye evolved independently—and in stunningly similar detail—in the different groups, and is radically unlike, say, the compound eye of insects. On the other hand, the process by which eyes are formed at the molecular level in mammals and insects has remarkable commonalities. Given the emphasis by conventional evolutionary theorists on contingency and random mutation, it is hard to understand how such extraordinary similarities could have come about. But the way in which *types* are nested within each other and derive ultimately from a single overarching *ur-type* suggests that the similarity may not be so surprising after all. "From a Goethean typological perspective, these discoveries of profound relatedness among markedly diverse animals are consistent with the notion of the *One ideal organism*—at the most inclusive hierarchical level of the animal archetype."

Riegner suggests that, while the organizing principle we glimpse in the *type* "remains elusive," it is also "central to the biological sciences." He cites Henri Bortoft (1996, pp. 240-1) to the effect that, when we think the *type*, "what is experienced is not a representation of the organizing principle, a copy of it 'in the mind,' but the organizing principle itself acting in thinking."

This reminds me of Samuel Taylor Coleridge's understanding of idea and physical law, as summarized by the British semantic historian, Owen Barfield: "A true law of nature is not a rule generalized from particular observations of natural behaviour; it is nature behaving." We can, of course, think such laws in a superficial and abstract way. But when we think their idea profoundly enough, "the very law [idea] itself is also the power" (1971, p. 126). Much the same could be the said of the Goethean *type*. The main obstacle to recognition of the truth Goethe and Coleridge saw remains our modern difficulty in (1) experiencing with sufficient vividness the dynamism of ideas, and (2) in perceiving the world as an outward expression of this dynamism. SLT

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Highlights from our Summer Courses

Evolution: Pattern and Surprise

For a week in June, twenty-one individuals joined Craig Holdrege, Henrike Holdrege, and Nathaniel Williams for an intensive exploration of biological evolution. The course integrated scientific and artistic explorations. A participant commented, "I enjoyed the interplay and resonances between the three activities of projective geometry, discussion of evolution, and sculpture." Another added, "The three strands played off each other nicely; each one offered its own 'ahas' and its own puzzles, and as the week progressed some of those phenomena shed light on each other."

Having made some notes on Craig's talks throughout the week, I (SLT) can offer a few glimpses of the world of observation and thought he introduced us to:

"Until we understand organisms, we cannot possibly understand their evolution." If a single idea should be flagged as fundamental to the course—and as underappreciated within the larger community of evolutionary biologists—surely it is this. Evolutionary theory has long been dominated by the conviction that changing gene distributions within populations tell us just about the whole story of life on earth. A hopeful sign today is the increasing recognition that the gene has been toppled from its pedestal as the decisive explanation for the organism. Biologists are more and more noticing the whole organism as an integral unity, and as they do so, we can expect a transformation of evolutionary thinking.

When we look at the series of leaves upward along the stem of an herbaceous plant (see figure on page 5), some of the lower leaves may suggest what the next higher leaves will look like. We might learn to expect a certain type of continuing transformation. But it is another matter altogether to predict the flower out of the leaves. Much the same holds for our being able to predict the frog from a tadpole, or—to shift from individual development to evolutionary development—the modern horse from a fox-like ancestor. In all these cases, we recognize that something new has arisen.

However, once we do see the later forms, we can observe a relatedness. The new was not something random. In fact, the end of a series of forms may be the best clue for interpreting the whole. In any case, the series itself, as a whole, is the fullest expression of the unity we are looking for. And this recognition of the whole enables us to say: "The frog takes hold of the tadpole in order to become a frog." This is very different from the building-block model of the organism's development.

The embryo doesn't *develop into* the adult, but is a field of potential in which the adult can appear. Likewise, you and I are not simply a bacterium that evolved, because we can't *derive* the human from the bacterial. But we could not be here without the bacterium. There has been a stream of development. And, not incidentally, one of our connections to all other things (which at the same time distinguishes us from them) consists in our ability to think our relations to them.

The transformation we see in organismal development and evolutionary sequences is reflected in our own learning processes. Suddenly we gain a new insight that is not a mere logical or automatic implication of past thinking. And yet, in hindsight, we can recognize it as part of a coherent time series. We can bring this truth to bear upon our study of evolution itself: there is required a kind of open receptivity to new thoughts as we contemplate the evidences, and out of this openness and these evidences, a new insight may arise—a new form in an organic thinking process.

Life isn't something we *see* in an outward sense, and neither do we *see* development. Dynamic activity as such is never something we see directly. Yet, in talking about these things, we are not just speculating. Rather, we strive to realize how we must *think* in order to "see" the phenomena—in order to bring the phenomena to appearance in their meaningful relationships.

Again: "Until we understand organisms we cannot possibly understand their evolution." One sign of things to come may be the recent remark by Denis Noble in his President's Address to the International Union of Phyiological Sciences: "The 21st century can look forward to a new synthesis that will reintegrate physiology with evolutionary biology."

"A challenging and rich course. In many ways it was itself a manifestation of diversity in wholeness and vice versa. … In the experience entirely new sets of questions and perspectives arose, and now have to be engaged—dealt with in their challenging wholeness. The teaching was imaginative and precise. The combination of the three—the artistic and mathematical along with the consideration of evolution itself—provided new and challenging questions and hints of insight. So everything remained alive" (Emeritus Professor, on the evolution course).

"Outstanding! [The experience raises] the question of how much we as adults need to participate in discovering the concepts versus having them presented. By introducing some of the preliminary ideas this way, Craig was able to take us much further so we could get to the final "ahas." Everyone was respectful and knew how to listen to each other and allow the subject matter to be presented without constant challenges coming out of the individual's agenda" (High School Science Teacher, on the evolution course).

The Four Elements: Earth, Water, Air, and Warmth

There is much we can immediately notice about water. Its droplets flow together and lose their identity, unlike, say, rocks. Creeks and rivers meander, forever changing their beds unless forcibly constrained by human intervention. Like fluids in general, water cannot be compressed, a fact making hydraulic technologies possible. And water's great capacity to absorb heat plays a large role in shaping climate and weather patterns. We can, in a disciplined way, take such qualities into ourselves imaginatively, assisted by writing, drawing, painting, sculpture, or the arts of movement. This in turn may open our eyes to processes of change and transformation in the world, in which water is so often instrumental.

Similarly, each of the four elements offers its own instruction of our understanding. And when we compare and contrast the elements, their teachings become particularly forceful.

The study of the four elements provides a doorway into a qualitative perception and understanding of nature-as-process. In a week-long course in July, Henrike Holdrege led phenomenological studies of the characteristics of the different elements and their interrelations, while artist Laura Summer led painting sessions relating to the different elements. Here are some comments by participants:

"The focus on close and patient observation was great, especially as the focus was on what was observed rather than conclusions or what we 'know'. I really like your teaching style and that combined with conversations after and between sessions has helped me crystallize my understanding of the connection of things in this natural world, techniques in my work and methods/approach to teaching. I'm inspired to lead more through teaching observations than through stating direction" (Software Engineer).

"I really enjoyed the experiments and observations—gave me ideas for teaching. I also liked the context of what is phenomenology and how it is different from traditional scientific approaches" (Middle School Teacher).

"I very much appreciated the experiments—the entry into a scientific understanding of the elements. My own approach has been more through human behavior and observation of the world around us. I have some new 'fruitful concepts' to augment my further looking/seeing/experiencing" (Adult Educator and Author).

"Henrike worked hard to bring us demonstrations that enlivened our study. Our discussions after the demonstrations were exciting for me and very energizing. I will be teaching physics and chemistry this year in grade 7 and I never expected that this course would so directly help me with this" (Middle School Teacher).

Here, There, and In Print

At the Institute

• ***Still Ahead: Talk on radioactivity.*** Sunday, November 17 (3 pm) Johannes Kühl will give a public lecture at The Nature Institute on “Gestures of Radioactivity and its Effect on Life.” Johannes is a physicist and director of the Natural Science Section at the Goetheanum in Dornach, Switzerland.

• ***Open house celebration.*** At the end of May we celebrated the completion of our new building, and over sixty people attended the event. The program included musical contributions by Paul Hasse, Eric Müller, and Christina Porkert, together with personal reflections upon the work of the Institute. Henrike Holdrege gave a talk on “Why Goethean Science?” that outlined the central features of the approach to research and education we attempt to develop and practice at The Nature Institute. Board member Douglas Sloan situated the Institute’s work within a concise yet sweeping portrayal of its historical and philosophical background. He highlighted the need to develop a science that addresses the world’s qualities and supports an ethical relation to the natural world. Nature Institute director Craig Holdrege followed with a slide show reviewing key aspects of the Nature Institute’s development over the past fifteen years. Board member Signe Schaefer concluded with some personal reflections upon the Nature Institute’s mission and role in the world.

• ***Nature, culture, and landscape.*** In June, Jean-Michel Florin, co-leader of the Agricultural Section at the Goetheanum in Dornach, Switzerland, gave a public lecture at the Institute on “How Can We Integrate Nature and Culture in the Design of our Landscape?” He discussed how the idea of landscape has evolved in European culture since ancient times, and showed slides from a variety of painters to illustrate how landscape is an ever-changing interface through which nature and the human world interact. It became clear how most European landscapes are in fact cultural/agricultural landscapes that have deep roots in the past. His reflections gave pause to think about how differently landscapes have developed in North America since its settlement by Europeans. There has been, it seems to me (CH), much less integration of urban, agricultural, and natural environments in the U.S.

• ***“Inner and Outer Light.”*** In this September talk Henrike gave a variety of striking examples showing how our experience of the visual world emerges out of the interplay of “inner light” — intentionality, learning, and thought— with the light of the sun and other sources of illumination. It became clear that our inner light can color what we see, but this light can become ever clearer and more illuminating when we consciously and carefully attend to the manifold and changing aspects of phenomena we encounter.

• ***Cleaning up the land.*** In late September we held a Volunteer Work Day to do landscaping on the Institute’s property and trail clearing in the 29-acre wetland preserve of which we are stewards.

• ***Monday Nights with the Stars.*** Again this fall Henrike leads three evening sessions (September 30, October 28, November 25) on the night sky. This time she collaborates with the eurythmist Jeanne Simon-MacDonald.

• ***Social science as Goethe might have done it.*** In October Christopher Schaefer gave a talk on "Perceiving, Understanding and Transforming the Social World: A Goethean Approach." In the talk and ensuing conversation, Chris explored the contours of a Goethean phenomenological social science—one capable of overcoming the often sterile and control-oriented, causal approach of the western social science tradition. Drawing on Steiner, but also on Max Weber and other continental thinkers, he described ways of reconceiving the social world that honor human freedom and dignity. Chris is a social scientist who taught at MIT, Emerson College (UK), and Sunbridge College. He is currently co-director of the Center for Social Research at the Hawthorne Valley Association. He is author of several books, including most recently, *Partnerships of Hope: Building Waldorf School Communities* (AWSNA Publications, 2012).

• ***Special connections.*** The Nature Institute's activities are also linked to other organizations or special groups. Starting in late October, Henrike will teach phenomenological optics and color on seven mornings to the students of the Free Columbia Art Course. Then in November, we will host a meeting of the Natural Science Section of the School for Spiritual Science. Craig and Henrike will guide sessions on "Experiencing the Inner Qualities of Animalness and Humanness." And, also in November, we will host a one-day invitational colloquium on atomism and quantum theory for scientists and science teachers, led by Johannes Kühl. (See also Johannes' public lecture, described in the first item above.)

Out and About

• ***Food Quality Gathering.*** What could be more important these days than understanding more deeply the quality of our food? A group of about twenty educators, scientists, journalists, and farmers (organic and biodynamic) met at the Omega Institute in Rhinebeck, New York, in September to exchange ideas about food quality. Henrike and Craig participated.

In the western world, assessing food quality has been reduced to assessing amounts of different nutrients. But is a box of cereal promising 100% of required vitamin intake nutritious? What about the sensory qualities of food (texture, taste, aroma)? Or the way a plant is grown or an animal treated? Or the quality of soil in which the plants grow? Or the quality of relations between producers and consumers? Or the quality of the dinner table conversation? In shared knowledge about all of these areas a complex and rich picture of food quality began to take form. The gathering marked the formation of a working group to further understanding and awareness of holistic ways of viewing and producing food quality.

Biodynamic farmer Jean-Paul Courtens, whose Roxbury Farm CSA in upstate New York serves over 1,000, characterized the session Craig led on "Schooling the Perception of Qualities" for his CSA members in the following way:

> "One workshop leader led us through an exercise whereby we discovered an apple with our full sense perception. He brought three apples with him from the same tree. One was red, the other mixed red and green, and the third one was almost green. We first carefully looked at it and then he sliced it in small slices. First we touched the apple, then we smelled it, and finally we experienced the full flavor by placing it in our mouths and chewing on it. When you do a mindful exercise like this, you realize that we hardly ever experience our food to the fullest extent. We eat because we are hungry; but as the exercise taught us, mindful sense perception greatly enhances our experience of the world. It is so different getting to know an apple by eating one slice over the course of 15 minutes. For most of the participants it was a mind-blowing experience and, yes, the apple was very good."

• ***At Schumacher College.*** In September Craig traveled to the United Kingdom, where he taught a one-week course on Goethean Science for the students of the Holistic Science Masters Degree program at Schumacher College. He also gave a talk on "Thinking Alive With the World: Cultivating the Roots of Sustainability" at the South Devon Waldorf School and at the Rudolf Steiner Centre in central London. He gave an all-day workshop, attended by teachers and teacher education students, at the London Waldorf Teacher Education program. The topic was "Cultivating Living Thinking" in education. At the Ruskin Mill Trust, Craig spent an afternoon and evening in a colloquium with scientists, educators, and farmers, sharing ideas about phenomenological methodology. Finally, he visited paleontologist Judyth Sassoon at the University of Bristol, who works with Goethe's approach to understand patterns in the fossil record of reptiles.

• ***At the New York Academy of Sciences.*** Craig was invited to speak in early October to the members of the Lyceum group of the New York Academy of Sciences on the topic of "Goethe and Science."

• ***Henrike in California.*** John Gouldthorpe, a long-time friend of The Nature Institute, has begun a venture in Point Reyes Station, California, that he calls "The Creative Compound." He describes part of what inspired it this way: "Even though the leading edges of our contemporary and accepted science may speak of wholeness, they do so in abstractions. Even if you do understand what the new physics is alluding to—strongly suggesting that we are a part of everything and that everything is part of us—it is not an experienced fact. It can be thought, but it is not a fact that you can feel. Contemporary science's way of making sense, its style, precludes this uniting of fact and feeling. We can feel good about what the facts suggest but we can't really feel the facts. Goethe the artist devoted his life to creating an alternative science, a science of wholeness, a science that unites head and heart, body and mind."

The Creative Compound has begun offering lectures and workshops on Goethean science. The inaugural event was a workshop conducted by Henrike: "Color Between Light and Darkness—Atmospheric and Prismatic Color." John wrote in his notice about the workshop: "I had the privilege of working with Henrike in the summer of 2009 at The Nature Institute and found her to be a rigorous and delightful teacher. She will be guiding us through the experiments with light and color as Goethe and Newton did, creating the atmosphere where their insights can become our own. It is an honor to have Henrike be our first teacher of science at the Creative Compound."

• ***At Chestnut Ridge, NY.*** In September Henrike participated in a conference on "The Challenge of Objectivity in Spiritual Research" at the Threefold Educational Center. As one of six research grant recipients, she presented her work in mathematics under the title, "Mathematics—a Preparation for Spiritual Scientific Research."

• ***Book signing.*** At the end of October Craig gave a short presentation at the local Chatham Bookstore about his new book, *Thinking Like a Plant: A Living Science for Life.* Afterwards he engaged in a conversation about the book with Thomas Chulak, co-owner of The Chatham Bookstore, and held a book-signing session.

• ***In New York City.*** Craig gave a talk on "Living Thinking: Developing a Deeply Ecological Consciousness" at the World Goodwill Symposium on November 2 in New York City.

In Print and Online

• ***Thinking Like a Plant.*** Lindisfarne Books has released Craig's new book, *Thinking Like a Plant: A Living Science for Life.* The book is crafted as a practical guide for developing what Craig calls "living thinking." Craig argues that this radical new, life-infused way of interacting with the world is just what we need to meet our environmental and social predicaments with courage and skill. The book is intended for educators, scientists, farmers and home gardeners, students, environmental advocates, and general readers as well. Look for more about it—including early reviews and information about ordering—on p. 13.

• ***"Leave No Child Inside."*** A book with this title, which has been newly released by *Orion* magazine, contains a collection of articles that have appeared in that publication. One of the articles is Steve's 1998 essay, "Why Is the Moon Getting Farther Away?"

The article is also available at http://netfuture.org/1998/Apr3098_70.html.

The book itself can be ordered from Orion Books: http://www.orionmagazine.org/cart/index.php?crn=207.

• ***On Intelligent Design.*** Over the years we've had inquiries about the theory of intelligent design, but have never had much to say. Now we've at least begun to remedy that. Steve has published an article commenting on a book called *Darwin's Doubt,* written by Stephen C. Meyer of Seattle's Discovery Institute. While intelligent design theorists rightly point to many of the troubles facing current formulations of the theory of evolution, Steve's suggestion is that the battles between ID proponents and mainstream neo-Darwinians arise from the common ground occupied by both sides. Both parties found their arguments upon "natural process" viewed in a materialistic sense, and therefore neither party "officially" recognizes the wisdom that is immanent in the organism itself. The proponent of intelligent design has removed this wisdom to an external designer who engineers organisms from the outside, and the conventional biologist has removed it to an abstract and incoherent (but god-like) principle of natural selection that likewise operates on the organism from outside.

The article appears in Steve's online notebook, "Rediscovering Life" (see next item).

• ***Toward a Biology Worthy of Life.*** This online project of Steve's has been rapidly expanding. And in addition to the new content, it also now has a more convenient and descriptive web address: BiologyWorthyofLife.org — which is part of the larger Nature Institute website. One feature of the project, added since the last issue of *In Context,* is an online notebook, or journal, that also has its own web address: RediscoveringLife.org. Recent postings to the notebook include these:

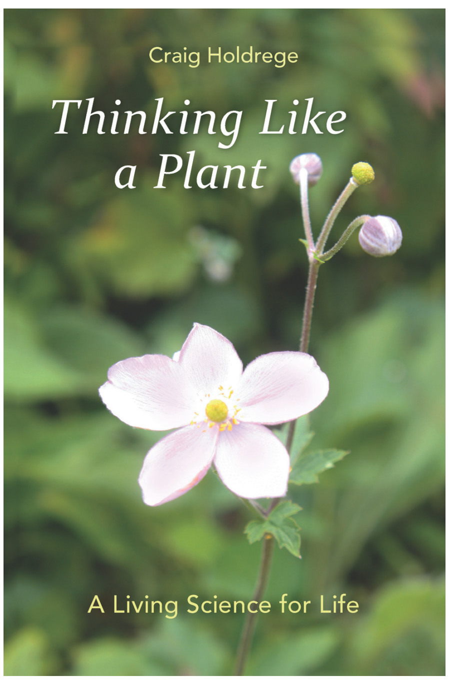
A sectarian quarrel? Intelligent design and neo-Darwinism — a commentary stimulated by Stephen C. Meyer's book in defense of intelligent design theory, *Darwin's Doubt.*

Will the real Walter Gilbert please stand up? — an update on crucial results now emerging from the world's molecular biology laboratories: we harbor not just one genome in our bodies but, in the typical case, many somewhat different genomes. We are, in the standard terminology, genomic mosaics. What does this mean for our understanding of genes and organisms?

Shattering the genome—This article, regarding a remarkable organism capable of repairing a genome broken into hundreds of fragments, is reprinted in a slightly abbreviated version here on p. 3.

A thousand-stranded tapestry: how organisms employ their genes — an introduction to a massive collection of notes from the technical literature dealing with the regulation of the genome by far-flung processes within the organism.

There is also a new topical index providing convenient access to all parts of the "Toward a Biology Worthy of Life" project. You'll find the index at BiologyWorthyofLife.org/comm/inx.htm.



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Thinking Like a Plant

A Living Science for Life

by Craig Holdrege

"Anyone interested in fostering a cultural revolution to develop a 'land ethic' reflecting an 'ecological conscience' that can enhance 'the capacity of the land for self-renewal,' as Aldo Leopold advised, should definitely read this book."

— **Frederick Kirschenmann,** author, *Cultivating an Ecological Conscience: Essays from a Farmer Philosopher*

"A field guide to new ways of thinking . . . offers practical exercises that invite us to overcome the materialistic, reductionist world view with a holistic way of knowing and experiencing phenomena. Holdrege points the way to a new, integral consciousness that is desperately needed at this moment in time."

— **Martin Ping,** Executive Director, Hawthorne Valley Association

"The best books are ones that offer an epiphany—a flash of insight that opens a world we'd never known, inviting us to explore its riches. *Thinking Like a Plant* is a book of that kind. The wonderful beings it reveals are ones we see and touch everyday but blithely ignore, to our detriment. What plants have to teach us will enrich our lives and perhaps even save the planet."

— **Langdon Winner,** Professor, Rensselaer Polytechnic Institute, and author, *Autonomous Technology*

Order through your local bookstore or directly from The Nature Institute (518-672-0116; natureinstitute.org/store) or from steinerbooks.org.

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From Mechanistic to Organismal Biology

E. S. Russell

We continue here our effort to "resurrect" some of the remarkably prescient writings from scientists before the modern era of molecular biology—a scientist in this case whose criticisms of the early development of genetic theory sound like they could have been written today. The following text is excerpted from Chapters 9 and 10 of E. S. Russell's The Interpretation of Development & Heredity: A Study in Biological Method, *published originally in 1930. For some notes about Russell, see "When Holism Was the Future" in* In Context #22 *(http://natureinstitute.org/pub/ic/ic22/russell.htm).*

The Process of Abstraction

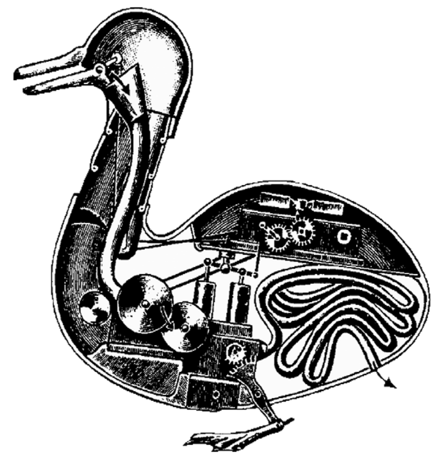
If we consider the various ways in which, for the purposes of science, abstraction is made from the living reality of the organism, we shall see how the different theories of development have arisen, and how their character has been determined by the mode of abstraction they adopt.

Biology occupies a unique and privileged position among the sciences in that its object, the living organism, is known to us not only objectively through sensory perception, but also in one case directly, as the subject of immediate experience. It is therefore possible, in this special case of one's own personal life, to take an inside view of a living organism.

When we conceptualize this living experience, we arrive at a definition of organism which, though it is abstract and schematic as compared with the experienced reality, is yet rich in content as compared with the still more schematic representations commonly employed in biology. The concept of organism which we derive from a study of direct experience is that of a continuing psycho-physical unity or individuality, which acts as a whole in relation to its environment.

The first stage of abstraction from the concrete reality of organism as experienced is the concept of organism as a psycho-physical unity or individuality.

The second step along the path of abstraction—namely, the elimination of the psychical—is one which nowadays is almost universally taken as a matter of course. It is a step of immense importance, for it introduces at once a dualism of matter and mind, and creates between them a dividing line which can never be crossed. To reintroduce mind into living things, to reconstitute the living unity, it is necessary to have recourse to such lame expedients as psycho-physical parallelism or psycho-physical interaction, or to adopt some form of dualistic vitalism. With the psychical aspect eliminated, the organism becomes a material system, similar in nature to, though more complex in structure than, other material bodies.



The complexity and variety of organization naturally provoke investigation, and give rise on the one hand to the science of organic form, in which types of structure are distinguished and their variants classified (morphology), and on the other hand to the study of the functioning of the different types (physiology). Morphology tends to remain a formal and abstract science, until it is revivified by the study of function; physiology develops very soon the concept of the organism as a complicated mechanism. Here two somewhat diverse points of view emerge—the teleological and the dynamical.

A machine is definitely a teleological construction, and the working of its parts can be fully understood only if their relation to one another and to the action of the whole be realized and grasped. The same view can be applied to the organism, which may be regarded as a teleological mechanism or machine, albeit of extreme complexity. The teleological point of view has undoubtedly great heuristic value in biology, and is in fact much used.

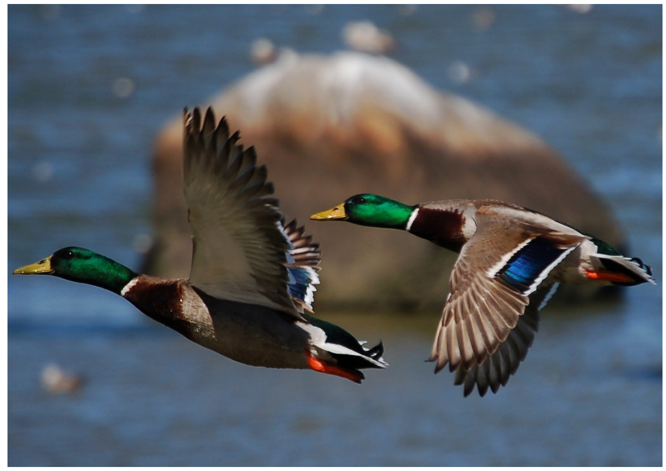
But the progress of physico-chemical study applied to the living thing has shown that the organism cannot be separated from its environment, with which it maintains the closest relations of interchange of matter and energy. Hence the conception arises of the organism as a physico-chemical system, standing in closest connexion with its physico-chemical environment. The simple concept of the organism as a formed machine is then replaced by the more general concept of it as a dynamical system. From this to the application to the organism of the general philosophical concept of material determinism there is only a step, and the organism tends then to become merged in, and hardly distinguishable from, the general flux of material events.

Abstraction from the living reality of organism reaches of course its highest degree in the mathematical or statistical treatment of living things. Here the organism is regarded merely as a numerical value—a number, a weight, a dimension. Mathematical laws of growth, for instance, may be worked out, in which the organism is treated simply as a quantity which increases in accordance with a certain formula. Clearly such formulation gives only the most general and abstract account of the process, highly useful though it may be within strict limits.

To recapitulate the main stages of abstraction from the organism as a whole—we get from the *living reality* as *experienced*, which is our ultimate standard, *first,* the primary abstraction or conceptualization as *psycho-physical unity* or *individuality*, from which may be developed the organismal theory of living things, and *second*, by abstraction from this of the psychical aspect, the ordinary 'scientific' conception of the organism as a *machine*, or more generally a *physico-chemical system.*

Of Wholes and Parts

The use of analysis is characteristic of science generally. Given a complex body, the chemist proceeds immediately to resolve it into its elements, to determine their relative proportions, and in some cases their architectonic arrangement. The same tendency is shown very clearly in biology. Given an organism, the morphologist's first thought is to discover its structure in minutest detail, to resolve it into its constituent organs and cells and their arrangement. The same process of analysis is applied to what appears to be the ultimate vital unit, the cell; this is decomposed into its constituent parts, nucleus, cytoplasm, chromosomes, mitochondria, and so on, and each of these elements is further resolved as far as may be into smaller parts, as for instance chromomeres, linin threads, and granules of all kinds. The process is even extended beyond the limits of microscopical vision, and hypothetical units, such as biophors, bioblasts, and genes, are freely invented to fill the gap between the just visible units and the complex colloidal molecules which make up the bulk of living matter. The method of morphological analysis leads then to a biological atomism, analogous to the atomism of the chemist.



From the physiological side also there starts a similar process of analysis or decomposition. The physiologist studies for choice isolated organs or organ-systems – the properties of a muscle-nerve preparation, for example, or the functions of the isolated heart. Even when he studies a major organ-system as a whole, the nervous system for instance, his method remains analytical; he resolves the action of the nervous system into the action of reflex arcs in their interconnexion with one another.

Now this analytic method, employed both in the study of form and in the study of function, is quite indispensable in biological research, and has yielded extremely valuable results. It is essential also for organismal biology. But we must note that it necessarily entails abstraction. The initial step which leads to abstractness of treatment is of course the isolation and definition of parts and part-processes as such. To define is to separate, and to separate is to ignore or to disregard in some measure the relations with other parts and with the whole. In the living thing there are in actuality no separate parts, no separate processes, for no part can be adequately characterized save in terms of its relations to the whole.

By the process of morphological analysis we can, for instance, resolve the organism into its component cells, but the cells so distinguished are abstract morphological units, characterized statically, in terms of structure. Actually the living tissue-cell is indissolubly linked up, by reason of its functional activity, with the neighbouring cells, and, through the *milieu interne* and the nervous system, with the general activities which the whole organism is pursuing. The tissue-cell takes part in the activity of the whole, and it is dependent for its own continued existence as a living part upon its manifold functional relations with the whole. If we distinguish it as an independent unit or component we necessarily abstract from its full reality; we disregard its functional connexions or relations with the whole, and form a simplified and static conception of it.

In the living thing there *are* no completely separable or independent parts; if we distinguish separate units or components it is at the cost of artificially simplifying our definition of them by abstracting from their continuing relations with the activity of the organism as a whole. It is primarily because the parts or constituents so distinguished are to a large extent abstract that it is impossible fully to reconstitute from them the whole from which they are themselves derived by the process of analytical abstraction. This is true even if we characterize them physiologically.

Contrast in this respect a machine. The machine has separate parts; it can be taken to pieces and put together again; its parts can be adequately characterized in terms of their own structure, apart from their relations to the machine as a whole. This is not the case with the organism. Here the parts can be adequately characterized only in terms of their functional relations to the organism as a whole. These relations, which are manifold and subtle, involve time and process, a taking part or merging in the total activity of the continuing unity which is organism.

The unity of the organism is accordingly not decomposable without loss, and cannot be resynthesized in its original completeness from the abstract components distinguished by analysis. We may sum this up in the following cardinal law of biological method: *The activity of the whole cannot be fully explained in terms of the activities of the parts isolated by analysis, and it can be the less explained the more abstract are the parts distinguished.*

Since analysis is necessary for biological science we must accept the fact that our biological results will be to a certain extent abstract and schematic, and we must strive to correct this abstractness as far as possible by distinguishing only such elements as are concrete and biological, not physico-chemical and abstract, and by carrying out as complete a reconstitution or reintegration of such elements as may be possible.

It follows from what we have said that the parts cannot be understood save in relation to the whole, and so we arrive at our second law of biological method: *No part of any living unity and no single process of any complex organic activity can be fully understood in isolation from the structure and activities of the organism as a whole.* To regard any process or structure by itself without relating it to the general activity of the organism is to deal with something which is in large measure abstract and unreal. To re-invest it with some degree of concrete reality it is necessary to re-integrate it into the whole. Its isolation by analysis should be provisional only, and after analysis there should always follow re-integration. We know that the reconstitution of the original unity will be incomplete, but we must make it as complete as possible.

Particulate Theories

There is, however, a misuse of analytical or disintegrative method which leads to disastrous consequences. The organism is by this method resolved into cells, cells into their constituent parts, and the substance of the cell into hypothetical units, to which are attributed many of the essential vital functions. This fractionalization is a method of approach to the problems of heredity and development which has become traditional and habitual, so that nowadays any other way of looking at these problems is rarely considered, and it is of course the basal method underlying all particulate theories. It is generally, though not invariably, coupled with the idea that some at least of these ultimate units represent and give rise to, or at the least co-operate in the formation of, particular parts or characters of the organism. This idea of representative particles is, we have seen, a very old one, dating back at least to the Greeks, and revived again by Bonnet, Darwin, and Weismann. It derives some of its force and verisimilitude from the fact that certain characters appear to behave as units in inheritance—a particular lock of white hair, for example, may recur from one generation to another.

From facts of this kind it is easy, but illogical, to conclude that all characters of the organism are separable in inheritance, that the organism is, as it were, a bundle of separate characters, represented separately in the germ, which can be shuffled about, so that some of the offspring get one set, some another, and so on indefinitely. It may be remarked that to distinguish separate characters at all in the organism has necessarily something artificial and abstract about it. Obviously the number of characters that can be distinguished is infinite, but yet none of them is in reality separate from the rest. The lock of hair, for instance, clearly cannot arise apart from the organism which manifests it. Separate or separable characters are therefore to a very large extent abstractions. But the idea that the organism is a composite of separate characters, each of which is represented in the germ by a separate vital unit, seems to have a perennial fascination for the human mind.

The attempt to find an internal formative mechanism as the cause alike of heredity and development, which is characteristic of nearly all modern theories, results necessarily in this separation of agent and material, just as the attempt of the vitalists to reintroduce life into the mechanistic abstraction that stands for organism results in a dualism or opposition between the immaterial agent and the material mechanism which it in some way controls. In either case one arrives at a *Deus ex machina*. The nuclear organization, the germ-plasm, or the gene-complex of modern theories, is accordingly invested with semi-magical powers of control.

The organism is regarded as a collocation of subordinate parts, of units of diverse degree, but the problem of 'composition', organization, or wholeness is ignored, and attention is concentrated on the lowest grade of these units. These are supposed to represent the parts or the characters of the developed organism, and in some way, which always remains mysterious, to give rise to them in the course of development. (The hereditary units being the purest of abstractions, it is of course natural that their relations with the characters they determine should remain obscure.)

Hereditary units and 'determinants' of all kinds are pure abstractions; the process of analysis has been carried so far that it is impossible to reconstitute from these purely abstract elements the activities of the cell or the organism as a whole. All that is left then to the theorists is to smuggle back into the determinants or other 'parts' the powers and functions which belong rightly to the organism as a whole, and have inevitably been dropped out during the process of analysis. The concept of the organism as a whole, which has been destroyed by unrestrained analysis, is reintroduced surreptitiously, and the qualities and powers of the organism as a whole attributed to certain abstract and subordinate *parts* of it, just as to entelechy are ascribed powers and capabilities which properly belong only to the whole organism.

The Organismal Perspective

It is perfectly possible to frame a working conception of organism which shall be less abstract than that of mechanism and shall do less violence to the essential facts. Let us see if we can formulate such a conception. In the first place, the functional unity of the living thing must be emphasized. The activities of the parts work together for the good of the whole; the meaning of any functional activity can be understood only if its relation to the activity of the whole is known. It is not really possible to study adequately any one function, e.g. excretion, without taking into account its relations to other functions and conditions, as assimilation, circulation, the composition of the internal medium, and so on, and without determining what part it plays in the economy of the whole.

This teleological conception can, however, be applied also to a machine; this also is a unity, in which each part has a definite role to play in relation to the functioning of the machine as a whole. But a machine can properly be analysed into constituent and independent parts, whereas in the living organism separate parts can be distinguished only by the artifice of abstraction, and its unity is not decomposable without loss. The organism differs from the machine also in another respect, in that all its functions are directed to one or other of three great ends, namely the development of specific form and activities, the maintenance or restoration of such typical form and activities, and the reproduction of specific type. None of these broad characteristics of living things is shared by any machine.

We must therefore add to our first point – that the organism is a functional unity – the further characteristic that the functional activities of the living thing are essentially related to the ends of development, maintenance, and reproduction. Implied in this fuller definition are certain temporal relations of vital activities which are fundamental for our conception of organism. The organism is *not,* like a machine, a static construction, but a constantly changing organization of functional activities, which tends towards some end, and in such tendency is influenced by its past. Its activity is related both to its past and to its future.

That these are not vague general assertions made to bolster up a preconceived notion of the organism is made clear if we consider fairly and with an open mind the general activities of living things. That in development there is a definite progression to an end or goal, i.e. a reference to the future, cannot be denied. That the course of development is essentially influenced by the past history of the race is likewise difficult to deny, and we sum up such facts of the historical background of development in the laws of heredity and recapitulation. The reference to past and future is clear also in all cases of restitution or regeneration, and it is so obvious in behaviour as to need no pointing out. Reproduction too is essentially a preparation for the future, and its course is determined and defined by what, for want of a better word, one might call the organic tradition handed down by countless ancestors.

Let it be made quite clear that this reference to past and future is not necessarily or usually (so far as we know) a conscious reference on the part of the organism. It is, for example, necessary for description and understanding of the bald facts that we use the word 'end' in considering the phenomena of development, but it is not implied that the developing organism is conscious of the end or purpose which appears *to us* to be embodied in its development. Whether the organism makes conscious reference to the past and the future is really a point of minor importance; what is important to realize is that organic activities are objectively of such a character that we cannot fully understand them unless we consider them in relation both to the past and to the future of the organism.

When in an embryo there is formed an eye long before it can function, when we see the germ-cells segregated early and slowly coming to maturity, when we watch the mother-bird building a nest for eggs that are not yet laid, we must, if we are to understand these actions at all, take into consideration their essential reference to the future. When we see in the development of the frog the reproduction of stages passed through by its ancestors near and remote, the formation and destruction of organs which had significance is some distant past and now have none, when we see the mature eel setting forth on its dangerous journey to spawn thousands of miles away in the depths of the Atlantic, we must in accounting for these facts bear in mind their essential relation to the past history of the race; they can be understood only on the hypothesis that in some way or other the past of the organism and of its ancestors still influences its present activities.

Time then enters as an essential element into our definition of organism. The living thing at any one moment of its history must be regarded as merely a phase of a life-cycle. It is the whole cycle that is the life of the individual, and this cycle is indissolubly linked with previous life-cycles—those of its ancestors right back to the dawn of life. This is what we mean by the continuity of life. And the activities of the organism at any stage of its career can be understood only if they are reintegrated in the individual and the evolutionary life-cycles.

There is yet another characteristic to add to our concept of organism before it can be regarded as reasonably complete, and that is a characteristic belonging to the functions and activities themselves. The action of the whole has a certain unifiedness and completeness which is left out of account in the process of analysis. This unifiedness of response can best be illustrated by reference to one's own experience of living—one's actions for example in playing tennis are unified responses of one's whole physical and mental being at the time, and an analysis of them into their constituents would inevitably miss out the essential point, namely their accurate co-ordination and applicability to the situation arising. In our conception of the organism we must then take account of the unifiedness and wholeness of its activities. This is the more necessary since we have seen that the activities of the organism all have reference to one or other of three great ends, and that both the past and the future enter into their determination. Such characteristics can belong only to actions possessing a concrete reality which is not wholly exhausted by analysis into constituent elements or parts.

We have now sketched, in the very broadest outline, a conception of organism which is completely free from any mechanistic assumption, and seems on the face of it to fit the main facts reasonably well. Let us summarize our conclusions. We agree that biology is essentially the study of individual living organisms, that the individual organism, whether unicellular or multicellular, is the unit to which all biological concepts and laws must relate. The organism is essentially a *continuing* unity, and all its activities are directed towards the ends of development, maintenance, and reproduction; these have reference to the future and to the past of the organism, and cannot be understood unless these temporal relations are taken into account; its activities have a certain unifiedness and wholeness which makes them irreducible to processes of lower order; the action of the organism as a whole is therefore not completely explicable in terms of the actions of the parts, and still less in terms of physical and chemical action.

We cannot claim for organismal biology anything like complete adequacy, or a close approach to full understanding of the living thing. The full secret of life will always elude a purely scientific treatment; it may be experienced, imagined, and felt, but never completely pinned down and explained. Something will always escape definition and measurement. Nevertheless we may rightly claim that the organismal method gives us a biology less remote from the truth than the abstract and schematic account to which the materialistic assumptions would limit us. It gives us a unitary biology, in which the abstractness and excessive analysis of the materialistic method are avoided; it allows us to look upon the living thing as a functional unity, disregarding the separation of matter and mind, and to realize how all its activities — activities of the whole, and activities of the parts, right down to intra-cellular unities — subserve in co-operation with one another the primary ends of development, maintenance, and reproduction.

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with Craig Holdrege and Henrike Holdrege

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