In Context

Number 34 Fall 2015

The Newsletter of **The Nature Institute**

#34

Dear Friends,

Rather like an autumn cornucopia, this issue of *In Context* contains a rich and diverse yield, with something for everyone. You will no doubt be struck in particular by one element: with this issue we begin what we expect will be a continuing practice of printing the newsletter with full-color photos.

If you want color—in insects, birds, flowers—you can hardly do better than go to the Amazon basin. And, as it happens, Henrike opens the newsletter by taking you there. She offers her own retrospective on the summer's watery adventure upon the Rio Negro and Amazon rivers. The debut of our full-color format is the perfect occasion for presenting some of the snapshots from that excursion. For those of us living in northern climes, the Brazilian rainforest offers many revelations of an entirely different world. Henrike shares some of those revelations in her thoughtful reflections.

Bruno Follador, the newest addition to the Institute's staff, is a student of soil, agriculture, and landscape. He takes an active interest in the *culture* of the land, in all the meanings of that term. Here, he describes his work with chromatography as a tool for assessing qualitatively the condition of soil and compost. This work raises interesting questions about the relation between qualitative and aesthetic considerations, on one hand, and the more conventional, quantitative methods for judging soil health and fertility, on the other.

In his feature article, Craig tackles profound questions about the nature of organisms as *living beings* whose essential character lies first of all in their activity rather than their physical constitution. "When we say in biology something 'stays the same,'" he remarks, "we actually mean it continually *becomes* the same out of activity." Things don't explain doings; rather, the doings explain the things. In pursuing his question whether a genuine science of beings is possible, Craig continues his portrayal of the frog, begun in our last issue. It all leads in the end to a characterization of portrayal—a "portrayal of portrayal," you might say—whereby this descriptive activity can be distinguished, as a goal of biological science, from the more usual efforts at causal explanation.

On his part, Steve has also been attempting to track the organism as activity. But whereas Craig has focused primarily on the phenomenological study of organisms at a level where we have something meaningful to observe, Steve's effort has been to hear what contemporary researches in molecular biology might be telling us. Due to length considerations, we cannot present his most recent article here, but only some rather brief excerpts from a very much longer piece, together with a link to the full text.

Craig and Steve have both found valuable stimulus in the unexpected convergence of their paths. And they both find themselves drawn—from opposite sides, as it were—toward the fundamental challenge of understanding the evolutionary pathways of life on earth.

Craig Holdrege — Steve Talbott

Craig Holdrege — Steve Talbott

The Nature Institute

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Amazonian Impressions

Henrike Holdrege

In June 2015 Mark Riegner and Craig Holdrege led a twelve-day trip to the Amazonian rain forest in Brazil (http://www.natureinstitute.org/educ/2015_amazon.htm). Sixteen people from the United States and Brazil took part in the adventure, including our staff members, Bruno Follador and Henrike Holdrege.

In early June we arrived in Manaus, Brazil, a city of nearly two million people in the center of the Amazon rainforest, just three degrees south of the equator. Looking from the city's "old town" out onto Rio Negro, you would think you were looking at a vast lake. About twenty kilometers downstream of Manaus, the Rio Negro and the Rio Solimões flow together in what Brazilians call "the meeting of the waters." The Rio Negro drains the Brazilian north; Rio Solimões has its origin in the Andes of Peru (and is called the Amazon River by Peruvians and most of the rest of the world). Below the confluence of these two large rivers, Rio Amazonas (as the Brazilians call it) flows another nine hundred miles before it meets the Atlantic Ocean. Rio Solimões/Rio Amazonas flows from west to east through almost the entire width of a continent, receiving waters of numerous and large tributaries. It empties into the Atlantic Ocean, carrying twenty percent of all the fresh water that streams and rivers on earth bring to the oceans.

We took an excursion to the "meeting of the waters." There was a clear boundary visible between the two rivers. Rio Solimões carries tan, muddy, and nutrient-rich water, while the water of Rio Negro is dark, clear, acidic and nutrient-poor. We leapt off our small, motorized boats into the Rio Solimões and swam into the warmer water of the Rio Negro. It is not until sixty miles downstream that the two rivers have fully merged and mixed.

For the twelve days of our trip we lived on our "house boat" (which accommodated all participants and guides as well as the ship's crew), journeying through various tributaries of the Rio Solimões and the Rio Negro. Early June was near the peak of the high-water season. In some areas the water level was up to fifteen meters (nearly fifty feet!) higher than in the low-water season. Since the giant Amazon basin is very flat, the rising waters spread far into the forests. Many areas are flooded for four to six months, and some for nine months.

During our journey, the waters were still rising. We learned that they would peak around St. Peter's Day at the end of June. And people in Manaus were concerned whether the Rio Negro would, as in the past three years, flow over the harbor walls and flood the adjoining fish, meat, fruit, and vegetable markets. Because we were in the high water season, there were only a few occasions on which we walked on what the Brazilians call *terra firme,* into the rainforest. Mainly we entered the forests on small boats. You have to imagine that we were moving near the crowns of the trees with the forest floor twenty-five to fifty feet below us. I wondered about the vegetation of the forest floor and the smaller trees that were fully submerged. Were they dormant like our trees in winter? Sometimes we could see submerged leaves on branches of trees through the dark clear water.

During the high water season the rich fish life spreads out into the vast flooded forests. There are many fish that feed on fruits and seeds that fall from the trees. Among them are the large fruit-eating piranhas with jaws so powerful that they can crack hard casings of nuts. The much-feared carnivorous piranhas are also in the flooded forests during this time, so that it was safe for us to swim, almost daily, in the deep open river channels away from forest edges.

The people who live in the areas where the water level rises and sinks so strongly over the course of the year are faced with special challenges. Houses are built on stilts or rest on floating foundations of large horizontal wood beams that are lifted when the water rises. Some houses are abandoned during the high waters and re-occupied for the months of low water. In the high water season people move around in boats; sometimes wooden walkways connect houses with each other. Manioc cuttings that will be planted when the water has drained away (manioc flour is a staple) are securely stacked away above the high water mark.

Since we were moving beneath the forest canopy in our boats, we could observe at fairly close distance those tree-dwelling animals that would be one hundred feet up had we been walking in the same forest in November. We observed meter-long iguanas that spend most of their lives resting on tree limbs. Sometimes when they noticed us, they plunged into the water, and once right into our boat onto one of our trip participants—with no ill effects. Twice we saw large (maybe six to eight inches in diameter) beautifully brown- and beige-patterned, motionless boa constrictors. It was as if they merged with the tree limbs they were coiled around.

Many kinds of ants live on these trees. Since their bites can have unpleasant effects, you try to enjoy them from a distance, which isn't always easy as your boat maneuvers through the dangling air roots, lianas, and hanging tree branches. Termites build impressive nests on tree trunks and build tunnels along the trunks and branches as dark passages for moving from place to place without exposure to

Its back was toward us and, effortlessly, it turned its head to look down at the humans that were gazing at it. It didn't seem particularly impressed or disturbed by our presence.

A short distance away, another sloth in a *Cecropia* began climbing higher up in the tree. Picture the most gentle and slow movement with not the slightest abruptness, no halting and starting anew, no angularity, nothing fast or jolting. To say "the sloth climbed up the tree limb" cannot express what we saw, even if it most effectively employed its enormous claws. It would be more accurate to say "it flowed up the tree limb" in one uninterrupted stream of slow motion, similar to that with which viscous honey flows from your spoon. A beautiful and unforgettable sight!

the light. We saw wasp nests dangling from trees. Every nest and home must be built high enough to remain above water at the time of flooding.

Craig, with his interest in sloths, was rewarded by numerous sightings. After nightfall (the sun sets at about six p.m.) we would sometimes go out in the boats and the crew would search the crowns with spotlights. We saw many sloths. We also sometimes "saw" a sloth that turned out to be a patch of textured trunk or a tangle of branches and leaves. We could not always discern a baby sloth that was held by its mother when we were told that there was one. Our guides certainly had greater awareness and keener eyes than we did.

One morning we sailed through a village and encountered sloths in close proximity to the "road." They were in their favorite tree, *Cecropia*, which has a long spindly trunk and sparse foliage of large palmate leaves. One was resting high up in a tree fork. Slowly it turned its face toward us—with its perpetual smile "painted" on its face. Eventually it let go of the tree with its forelimbs until it finally hung fully outstretched, upside down. It held onto the branch only with the three large claws of each hind limb.

One afternoon while we were silently observing in the forest, with a faint rainbow and billowing clouds in the far distance, we became aware of squirrel monkeys in our proximity. They are small and delicate. Swiftly and skillfully they appeared out of the dense canopy to our right, a whole clan it seemed, and hurried along on branches, jumping to bridge a gap and then holding on to the next branch with all limbs, the long tail included. When they had reached trees at a safe distance, they halted and, it seemed, looked at us with some curiosity. Moments later we heard a faint noise that we first took to be a chain saw. From the captain of the ship we learned that these were the voices of howler monkeys.

We had several opportunities to watch howler monkeys with our binoculars later on. Mostly we saw them with their orange-red colored coats in the tops of high trees, in small groups, slowly moving about or feeding on leaves and fruits. They are the largest monkeys in the Amazon, and they carry their name rightfully. One night, before

broad trunks carried the most varied and exquisite gardens of epiphytes—everywhere plants growing on trees: bromeliads with leaf rosettes you have seen in pineapples; large-leaved philodendrons; varied greens of mosses and lichens; a variety of orchids, only a few in flower; ferns of various shapes and sizes. Each "tree garden" was an artistic masterwork in the arrangement of leaf shapes and sizes and shades of green. Sometimes there was no space unoccupied on those trunks. The most frequent host tree, I learned, can be translated as "the most beautiful of trees."

Observing and contemplating the intricately interwoven relationships of plant and animal life in the Amazon, I felt that our ideas of "struggle for existence" and "survival of the fittest" do not do justice to the reality of an ecosystem in which every element seems to contribute to the whole and is sustained by the whole. The epiphytes, for instance, are plants that live up on the branches and trunks of trees. The trees are their ground, and birds and other animals disperse their seeds. The epiphytes, in turn, are important for the growth of the trees. A multitude of creatures live in and on the epiphytes and the droppings of those same creatures enrich the rainwater that runs down the host trees. This "fertilizer" is immediately absorbed by mycorrhiza (a symbiosis between fungi and tree roots) and the root system of the trees—a system that is three times more dense than that of a forest in our temperate zone. The water *beneath* the root system proves to be nearly as nutrient-poor as the rainwater was in the first place.

Hardly any soil forms in these rainforests—something we could see the few times we walked through forests. You push aside a few leaves and meet a tangle of roots right on the surface. These rainforests grow *on* rather than *in* an extremely nutrient-poor soil. Everything is lifted up in this interwoven world.

The intensity and diversity of relations in this largest of all rainforests is unsurpassed. We all felt that it was an honor to be there, that we were in the presence of something we could hardly comprehend. On leaving the Amazon, I had no doubt that the vast Amazonian rainforest, whether by its health or its destruction, will have an impact on the health and life of our entire planet.

dawn, Craig and I heard an enormous sound through the open cabin window. We rushed to the upper deck and experienced what I later called "the voice of the Amazon." Imagine an uninterrupted roaring, with modulations, out of several deep voices, soulful and mighty, that continues for a good while. It is a powerful and eerie sound that resounds through space, remotely comparable to the roaring of lions. And then—to our greatest surprise—as if under the guidance of a great conductor, the howler-monkey chorus stopped suddenly. This was the case every time we heard them. Who gives the signal to end?

Early June, we found, is not the time of most abundant flowering; it is more a time of setting fruit and fruiting in many plant species. However, gliding past forest edges, our attention was caught by colors that stood out from the dominance of green: orange, yellow, beige, pale beige (almost white), deep purple, red. These spots of color, that you could easily mistake for flowers from the distance, revealed themselves through our binoculars to be bunches of leaves. They were new leaves often on only some branches of a tree. They looked delicate, fresh, and somewhat limp, hanging down in clusters. While the tree still carried its mature foliage, it was also "pouring out" new leaves, not yet green, on some of its branches.

On the last day of our trip we left the ship in three small boats at pre-dawn. The motors were turned off and the boats were propelled by paddling. We had agreed to observe in silence. The night sky was clear, and I could discern the constellations of the zodiac; Aquarius was high above us. There were the night sounds: distant howler monkeys and the unfamiliar voices of frogs and insects. A night hawk skimmed the water. When the sky brightened, birds called out and flew from their nightly resting places.

We glided in silence through water channels that narrowed ever more as we entered the forest. Massive trees with their

Portraying Soils and Compost: Color, Form, and Pattern

Bruno Follador

> "The healthy is at the same time the biologically sound and truly beautiful"
>
> —Ehrenfried Pfeiffer

"Compost happens!" Perhaps you have seen this statement printed on t-shirts or in farm-related magazines. Each time I read this I am always left bewildered: Yes, compost happens, but *how*?

Even after surveying the vast technical literature, one might still ask: What is compost? Do I have to turn it? Should I layer everything or mix it? How do I know if it is good or not? How do I know it is ready? And did it really happen?

Ehrenfried Pfeiffer, one of the pioneer's of the bio-dynamic movement, wrote:

> There is not just one compost for everything, nor is all the organic material or waste (from the moment it arrives in the dump or compost yard, and on through all stages of fermentation and decay) yet to be defined as compost.

Pfeiffer was one of the most important and influential soil scientists of the twentieth century. A central theme of his work was the question how one evaluates the biological quality of a compost or soil beyond mere quantitative chemical analysis. Along with his colleagues, Pfeiffer strove to develop new approaches to soil and compost analysis.

Color, Form, and Pattern

Chromatography was first developed by the Russian botanist Mikhail Tsvet, and described in his fundamental publications from 1903-1906. The method, with many variations today, allows the separation of the various ingredients in a fluid mixture. For example, by applying the mixture to a special filter paper, one can observe how, due to capillary action, different elements in the mixture are "soaked up" by the paper at different rates, forming distinctive patterns.

In the 1950s Ehrenfried Pfeiffer pioneered a novel way of working with paper chromatography to assess the qualities of humus in soils or compost. This new method, known today as Pfeiffer's Round Filter Chromatography, employs filter papers treated with silver nitrate. The organic substances, such as soil or compost, are mixed together with a solution of sodium hydroxide before application to the paper. The mixture is then poured into a petri dish, and is drawn up through a wick inserted through the middle of the paper.

Consider for a moment Figures 1 and 2. Each is a chromatogram of a compost sample.

At a first encounter, the absence of numerical values might leave the viewer lost regarding the worth and quality of each compost. There are no numbers or percentages indicating amounts of organic matter, nitrogen, potassium, or other elements. Yet, we might wonder: could the particular array of forms, colors, and patterns tell us something about how the organic matter has been decomposed and transformed?

Observe each chromatogram carefully, paying attention to all the nuances of form and color. How many different "zones" can you observe in each figure? Is there a relationship between each region? Are you able to see movement or stagnation in either of the pictures? Which

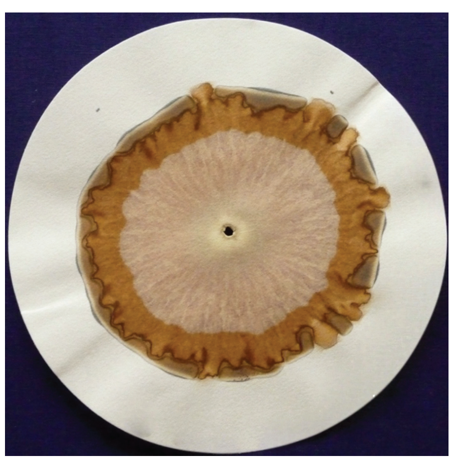

Figure 1

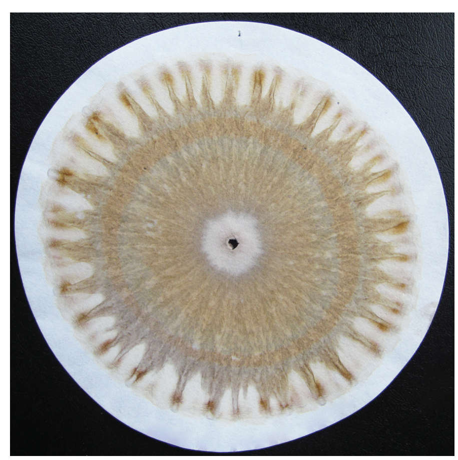

Figure 2

chromatogram seems more integral and whole? Which would you guess represents the healthiest and best compost?

Most viewers will probably have picked Figure 2. And, based on a wide range of separate assessments, it turns out that this is indeed the compost with the best quality. It is not so easy, however, to explain the relation between these separate assessments and the qualitative—one might even say "aesthetic"—features of the chromatogram.

But these qualitative features—form, color, and pattern—*are* related to objective aspects of the soil or compost sample. Various studies make clear how the different nutrients, organic substances, and humus fractions are separated by the capillary action of the paper. In "reading" the chromatogram, one necessarily pays attention to these details. This makes it all the more interesting when one notes how qualitative judgments cohere with, and add to, the information conveyed by the more abstract and "drier" analyses of the chromatographic image. When most reliable and comprehensive, however, these judgments are not casually arrived at. They arise only from a great deal of experience, and from attention to the entire context of the farm and its cultural practices. And, of course, direct observation of the soils and compost piles plays an essential role.

I would like to suggest, then, that the chromatogram can become a valuable tool in conjunction with a broad, contextual analysis of the health and fertility of a farm or garden.

Reading the Chromatogram

Let's ask ourselves how we might read these two chromatograms qualitatively, reserving judgment about the objective significance of our conclusions.

There is, clearly enough, a striking difference between the two chromatograms shown. In the figure at left we can observe a dark, grayish outer ring enclosing everything else. Directly inside it, there is a thicker, irregular, brown, and, we might want to say, "unharmonious" ring, about an inch thick. Occupying most of the figure is a large violet disc, with a smaller disc at the very center of the image. There is little interaction between these different zones, apart from the protuberances erupting from the brown ring into the outer, grayish belt. None of the regions is "relating" to the others. The figure as a whole gives the impression of stagnation.

The second figure looks rather like the iris of an eye. One senses in the whole a movement radiating centrifugally all the way out to the edge of the filter paper. Instead of a dark ring enclosing everything else, we find an open, light-beige outer circle. Spike-like formations interpenetrate this outer layer, and at the tip of each "spear" there are brown spots. These "spurs" correspond to the brown ring of the first figure. The inner main disc has brownish hues, instead of violet, and is filled with feather-like radiations. Unlike in Figure 1, each region harmoniously relates to and interpenetrates the other. The picture gives a sense of movement, development, and harmony.

Figure 1 represents an anaerobic and stagnated compost of very poor quality, while Figure 2 is a sample from an excellent humified compost.

I have shown chromatograms, at times a series of twelve samples, to groups as large as sixty people. Surprisingly enough, the majority of participants have always been able to identify the compost with the highest biological value, based on a qualitative assessment of the chromatographic images—this despite the fact that, in most cases, no one had had any previous experience with this particular method.

Chromatography offers a fresh and engaging possibility for farmers and gardeners to learn more about the biological processes taking place in their compost piles and fields.

A farmer once told me that, after having observed the chromatogram of his compost pile, he was able to better understand how to mix his piles and when to turn them. The picture *did not explain* what was wrong. But by *engaging* with the movement and patterns of the chromatogram in relation to the life of his pile, he was able to "see" what needed doing.

Ehrenfried Pfeiffer's groundbreaking work was to develop a pictorial method for *portraying* biological processes. Certainly there is a danger of using this method mechanically, analyzing images by looking only for the presence or absence of the most obvious forms and colors. But I hope to have at least hinted at the possibility that a sensitive, qualitative attention to the chromatogram might lead one to a fruitful engagement with the boundless contextual factors bearing on the health and fertility of soils, and on the processes by which "compost happens."

Since the fall of 2014, as part of the Living Soils project, The Nature Institute has established a small laboratory for employing Pfeiffer's Chromatography in support of research, workshops, and consultations.

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2015 SUMMER COURSES
at The Nature Institute

Out and About

It's been a busy half year for Nature Institute staff, not only at the Institute itself, but also (as noted below) at locations near and far—from the United Nations to the Amazon river basin, and from local Hudson Valley farms to a United Kingdom college. For the Amazon story, please see the article on page 3. Also, be sure to note the events still upcoming, described at the end of this listing and in "Fall and Winter Events at the Institute" on p. 11.

• **Harmony With Nature – At the United Nations**. In April, the United Nations General Assembly in New York City held a dialogue on "Harmony With Nature." Craig Holdrege was invited to moderate the dialogue, which was both an honor and a recognition of the Institute's work to bring human thought and action into greater alignment with the wisdom of nature. The event was the fifth dialogue of its kind that the UN has sponsored as an annual commemoration of International Mother Earth Day. You can find out more about the "Harmony With Nature" initiative at: http://harmonywithnatureun.org/index.html. We were also invited to contribute a brief position paper concerning harmony with nature and its relation to the United Nations' sustainable development goals.

• **Consulting with Local Farms**. In May, Bruno offered composting consultations to two organizations in the Hudson Valley that integrate farming into their special missions. One, the Center for Discovery, in Harris, is dedicated to serving children and adults with severe disabilities or with autism-spectrum disorders. The other, Stewardship Farms, is a rural development company in Stuyvesant that features a model farm to demonstrate best practices adapted to the ecology of the Hudson Valley.

• **At the Land Institute: Ecospheric Studies**. In June, the Land Institute and its president, Wes Jackson, hosted thirty-five scientists, educators, and artists from around the country and abroad at the Institute's Salina, Kansas, headquarters. The event was a two-day working conference on "Ecospheric Studies." The basic question was: what would an education program look like that is truly holistic and interdisciplinary? What are the best ways to foster greater awareness of the earth's ecology and to align human activities with it? Craig was asked to speak on Goethe's ecological/phenomenological approach. He emphasized that it is not only a matter of knowing *about* dynamic interconnectedness, but of transforming our ways of perceiving, knowing, and acting so that we ourselves become more dynamic.

• **Soil Fertility and Military Veterans**. In September, Bruno gave a half-day workshop at the Heroic Food Farm in Ghent, New York, on "The Art of Farm-Scale Composting." The Heroic Food Project is a non-profit organization with the mission of preparing and training military veterans for careers in sustainable farming, agricultural trades, and food entrepreneurship in a veteran-supportive environment.

• **Phenomenological Science and What Plants Can Teach Us**. In September, Craig taught a week-long course for students in the Masters of Science program in Holistic Science at Schumacher College in the United Kingdom.

• **Evolving Science**. In October, Craig delivered one of the keynote talks at an international conference concerned with the evolution of the Goethean approach to science. The conference was organized by the Science Section at the Goetheanum in Dornach, Switzerland, and was attended by scientists from around the globe.

• **Goethe in Texas**. Also in October, Craig gave two talks at Texas State University on Goethe's approach to science. He spoke to faculty and students.

• **Sustainability Education**. In November, Craig gave a public talk at the Waldorf School of Moraine Farm in Massachussetts on "Tending the Roots of Sustainability: Education and our Responsibility to Children and the Earth." He also led an all-day professional development workshop for educators: "Forming Living Ideas and the Significance of Experience-based Learning."

Still Ahead

• **Compost and Soil Health at Ecofarm Conference**. Bruno has been invited to be the main speaker at the pre-conference of the 36th annual Ecofarm Conference in Pacific Grove, CA (January 20-23, 2016). The theme of the pre-conference is Compost and Soil Health. He will also be giving a workshop at the main conference, which is the oldest and largest sustainable agriculture gathering in the western United States.

• **New Two-Year Program in Brazil: "Seeing Nature Whole."** Henrike and Craig have been invited to develop and teach a course in the Goethean approach to science, to be held in Brazil. They will be offering a four-week program during July 2016 and 2017 at the Associação Sagres, a center for adult education in Florianópolis in southern Brazil (http://www.asssagres.org.br/). They will teach in English, and all classes will be translated into Portuguese. The course is for people who seriously wish to apply the Goethean scientific methodology in their own work and carry it further.

Fall and Winter Events at the Institute

Highlights from our Trip to the Amazon in June 2015
Impressions and slides shared by Bruna Fogaça, Bruno Follador, Craig Holdrege, and Henrike Holdrege
Wednesday, September 16, 7 pm

Monday Nights with the Stars
A course in four sessions with Henrike Holdrege
Mondays, 7 pm: September 21; October 19; November 16; December 14

Outer and Inner Warmth
Talk by Henrike Holdrege
Friday, September 25, 7:30 pm

Outer and Inner Warmth — Phenomenological Studies
Workshop at The Nature Institute with Henrike Holdrege and Nathaniel Williams
Saturday, September 26, 9:00 am – 4:00 pm

An Introduction to Projective Geometry
A workshop in eight sessions with Henrike Holdrege
Tuesdays, 9 – 10:30 am, October 13, 20, 27; November 3, 10, 17; December 1, 8
Continued from the spring; new participants welcome.

Coming Alive to Nature: Plant Studies
A short course with Craig Holdrege
Mondays, 9 am – 12:30 pm, October 19, 26; November 2

Hands-on Farm-scale Composting
A workshop with Bruno Follador
Friday – Saturday, October 30 – 31

Volunteer Work Day
Saturday, November 7, 9 am – 1 pm

Coming Alive to Nature: Images, Color, Light and Darkness
A course with Henrike Holdrege
Monday mornings, 9 am – 12:30 pm, November 9, 16, 23, 30; December 7, 14

Plants and the Living Earth
Winter Intensive for farmers, gardeners, and apprentices, with Craig Holdrege, Henrike Holdrege, and Bruno Follador
February 7 – 12, 2016

Our interactions with nature will become ever healthier, and support a productive co-evolution of humanity with the natural world, when they are based on a deeper understanding of nature. Can we truly see and experience nature as dynamic, interconnected and whole? That is an underlying question that will inform the week's activities. The work will include careful sensory observation and just as careful attention to how we think about and judge the phenomena we are observing. We will focus our attention on these topics:

Earth, water, air and warmth
Practical exercises and observations to understand the essential qualities that inform all life on earth.

Plant study
Metamorphosis; plant growth and development in relation to the environment, with a focus on soil; domestication characteristics of food plants; assessing quality through our senses.

Soil, Compost, and Phenomenological Chemistry
Integrating composting into the organism of the whole farm; qualitative assessment; experiencing the qualities of the chemical elements carbon and nitrogen.

Mathematics Alive!
Weekend workshop for teachers with Henrike Holdrege and Marisha Plotnik
March 18 – 20, 2016

For more information, please visit our Calendar of Events: http://natureinstitute.org/calendar.

Thank You!

We are deeply indebted to those friends of The Nature Institute who have helped to sustain our work by contributing money, goods, or services between April 1, 2015 and September 30, 2015.

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Is a Science of Beings Possible?

Craig Holdrege

The wolf does not become a lamb even if it eats nothing but lambs all its life. Whatever it is that makes it wolf, therefore, must obviously be something other than the "hyle," the sensory material, and that something, moreover, cannot possibly be a mere "thought-thing" even though it is accessible to thought alone, and not to the senses. It must be something active, something real, something eminently real.

I read this passage from the nineteenth-century philosopher Vincenz Knauer (1892) for the first time about forty years ago while I was in college. It gave me occasion to reflect then, and it still does today. In one sense it is a straightforward thought: wolves eat lambs (and much else) and remain wolves; koalas eat almost exclusively eucalyptus leaves and remain koalas; frogs eat slugs and flies and remain frogs. All animals overcome their food to maintain themselves. And think of plants. Poppies, asters, and milkweeds, to name a few, all take in carbon dioxide, water, and some minerals, and with the help of light create their own living substance and form. But how different they are from the water, air, and minerals they take in, and how different they are from one another!

Knauer is pointing to the fact that organisms are activities. It is not the substance of the food that makes them what they are. It is the specific way of transforming and forming that makes the wolf a wolf, the frog a frog, the poppy a poppy.

We gain a most vivid sense of this creative activity when we observe the development of an organism. When a tadpole metamorphoses into a frog, virtually all tadpole characteristics are broken down and disappear—for instance, the long tail, the gills, and the long intestine (see Holdrege 2015). New organs form—four legs, lungs, stomach, teeth—while other organs reconfigure, such as brain, eyes, kidneys, and skin. The developmental process entails unceasing transformative activity. The resulting adult is wholly other than the larval tadpole in its bodily configuration, physiology, and behavior. What we in the end call the adult frog works its way into appearance—becomes flesh—through development.

The frog-as-activity does not cease to exist once it reaches adulthood. Certainly, there is more stability of form and substance in the adult. But the frog is always engaged in maintaining its form and continually building up, breaking down, and transforming its bodily substances, all in relation to its needs and what it encounters in its surroundings. The frog never "is" in a static sense. It is continually producing and maintaining itself. Its body is at any moment the result of ongoing creative activity.

But What About Genes?

I can imagine some readers are thinking: That is all fine and good, but it is the genes that make both tadpole and frog. The genes, after all, stay more or less the same during the life of the animal, and, for that matter, remain relatively stable for generations. They make the frog a frog. Just as we can say that the frog-as-body moves, so we can say the frog-as-its-genes makes the frog. There is always some "thing" (body, DNA) that is the doer. The "thing" is primary and all activity is simply the interaction of things (substances).

That is certainly our habitual way of thinking about how life works, and it is precisely the habit that I want to move beyond. I think that Knauer got it right: the organism-as-activity is something "real, something eminently real" and yet it is not some "thing" we can place alongside DNA, cells, organs, and limbs.

Yes, in an abstract sense the bare DNA sequence (the sequence of nitrogenous bases) in a frog embryo, in a tadpole, and in an adult frog is, generally speaking, the same. If we begin by applying the widespread notion that genes consist of portions of that sequence, then if the sequence stays the same, genes must stay the same. They are the stable and unchanging physical basis of the organism, while all other things may be different in the different life phases of the frog.

But if the genes are the "same" in embryo, tadpole, and adult frog, then can it be the genes that make these phases of life different from one another? This is worth pondering.

The conventional response would be: well, there are different genes that are acting at different times during development. So there's no problem; it's just that we don't know yet the total activation sequence of the ever-present DNA over time. But there is a problem, and it's hidden in the expression "genes acting." How do genes act? By being woven into the activity of the rest of the organism. There is a highly complex and variable series of interactions that occur when a gene "acts." (See Steve Talbott's article in this issue of *In Context* and the much more detailed consideration in Talbott 2015.) DNA is chemically modified (for example, via DNA methylation), brought into movement, repaired, re-arranged and more during the developmental process. To say that "DNA stays the same" is to say that certain sequential features can be found to be stably produced and reproduced over time. That is basically the same as saying: over generations the wood frog stays a wood frog. When we say in biology something "stays the same" we actually mean it continually *becomes* the same out of activity; it is not an unchanging thing.

There are about 20,000 – 25,000 protein-coding DNA sequences, or genes, in the human genome, as geneticists typically count them. But many more proteins are synthesized than this static view of genes might suggest. Over one million distinct proteins are thought to be formed in the human body. The synthesis of these proteins does require specific DNA sequences, but the relevant sequences are not simply lined up, waiting to be utilized. Their final specification occurs within the context of development and through the activity of the organism under changing inner and outer conditions. It has become clear, as stated in an article by biologists on "How to Understand the Gene in the Twenty-First Century?", that genes need to be "conceived as emerging as processes at the level of the systems through which DNA sequences are interpreted, involving both the cellular and the supracellular environment. Thus, genes are not found in DNA itself, but built by the cell at a higher systemic level" (Meyer et al. 2013).

At whatever level you consider — whether molecules (DNA, proteins, etc.), cells, tissues, or organs —you find interrelated activity. Surely the doings will always be connected to "things," but the "things" don't explain the doings. DNA acts "because" proteins interact with them and act on them; proteins exist "because" DNA enables their synthesis. Every "actor" in the biological drama is also always an "acted upon." All the mind-boggling interactions molecular biologists discover *make sense* within the context of the healthy organism. They are part of the performance of the organism, to use Kurt Goldstein's phrase (Goldstein 1995, p. 282). All the genes that "come into action" while the tail of a tadpole is being reabsorbed, or in the formation of the new type of hemoglobin in the nascent frog, are part of the unfolding story of the frog's coming into appearance.

The Organism: Being-at-Work-Staying-Itself

Inasmuch as we become aware of this formative, activity-nature of life, we also move beyond strictly spatial conceptions. We are looking not only for mechanisms ("this" causes "that"). Rather we seek to understand how each "this" and "that" is connected within the coherent life of the organism, a life that expresses itself in every form, substance, and activity, from eating a fly to producing a digestive enzyme.

Trying to adequately express the activity-nature of organisms in one word, Aristotle coined the term *entelechia.* This Greek word is usually transliterated into "entelechy" in the English language. It is often interpreted as indicating a kind of essence or life force that affects the material workings of the organism as if from the outside. But this is clearly not what I've been talking about and it is also not what Aristotle intended. In recent translations and commentaries on Aristotle's works, Joe Sachs creates unique English phrasings that he believes are more true to Aristotle's dynamic view of nature and creative use of the Greek language. Sachs translates *entelechia* as "being-at-work-staying-itself"(Aristotle 1999). Every organism is being-at-work-staying-itself. This phrasing points to the fact that the organism is an active agency. It indicates that we don't have two things—a being that is also active—but rather a single "being-at-work." It *is,* only inasmuch as it is *active*. And this being-at-work is also coherence; it is continually "staying-itself" as frog, wolf, or poppy amid ever-changing circumstances. As awkward as Sachs' expression is, to my mind it accurately suggests the reality we encounter in organisms. Moreover, through its awkwardness we are challenged to actually think about what we are saying, and becoming active in thinking brings us closer to what we are actually trying to apprehend—the active nature of the organism.

In the end it should not be so important what term we use. In fact, it may be best to use different expressions, depending on the specific context, in order to suggest our meaning—organism-as-activity, agency, being-at-work-staying-itself or, simply, being. So, yes, a science of beings is possible. But it demands moving beyond certain habits of thought and a different way of looking at life than is typical today.

Gaining a sense of the activity-nature of organisms is a first step or a first opening into a science of beings. Many pathways can then be taken. I want to suggest one here. Wolves, frogs, and poppies are very different kinds of organisms. Each is its own "being-at-work-staying itself." But what is the wolf's particular way of being itself at work, what is the frog's, what is the poppy's? In other words, can I engage in the specific way-of-being of a particular species or group of organisms so that the living world in its manifoldness and varied and unique expressions can show itself? What follows is such an attempt.

Portraying a Frog

A tadpole lives fish-like, immersed in and bound to a watery environment for the duration of its life before metamorphosis. During metamorphosis a whole new body form is created. As lung-breathing, four-legged animals, most frogs seek the land. Some stay in close proximity to their watery origin, others return to water only in the mating season.

Figure 1. A green frog (*Rana clamitans*). (Photo: C. Holdrege)

With their moist, permeable skin, frogs are never fully at home in a land environment with dry air and strong sunlight. They prefer humid conditions, and most are nocturnally active. Although the skin is a physical boundary, it is porous with respect to water. As a result, the water content of the frog's body can fluctuate strongly depending on outer conditions. A frog can lose over a third of its body mass through evaporation and still survive as long as it can replenish the lost fluid. Interestingly, frogs cannot drink through their mouths. Rather, they drink through their skin, especially their belly skin. A frog that is dehydrated can simply lie in a puddle and drink through its skin; or it can bury itself under leaves or in the soil and slowly draw moisture into itself. Desert frogs spend most of their lives in self-dug burrows (up to 90 cm deep—almost a yard) and slowly draw water out of the soil. Frogs can store large amounts of fluid in their bladders and distribute it as needed.

Frogs are dependent on warmth from their environment to maintain their body heat, so that body temperature fluctuates with changes in ambient temperature. They are generally sluggish in cool weather, and some frogs can survive for a period of time in the frozen bottom of a pond. They become active in warmer weather, but you generally do not find amphibians basking in the sun like thick- and dry-skinned reptiles (think of lizards and snakes) in order to warm up. They avoid direct evaporation-causing sunlight.

So we see how the frog is very open to its environment. Through its skin it is giving up fluid to the air and drawing fluid in from the surroundings. Even though it has lungs, a frog still inhales around 40 percent of its oxygen and exhales more than two-thirds of its carbon dioxide through the skin. And the frog's body temperature oscillates with the warming and cooling of its environment. In these ways it lives in intimate connection, behaviorally and physiologically, with the changing conditions. Or we could also say the frog participates in these changing conditions and is part of them. There is no clear boundary that indicates here the "frog" ends and there the "environment" begins. While we can say that the frog is a center of formative activity, this activity is wholly embedded within and dependent upon the larger fabric of interactions and substances that we call its environment. We can as little separate the frog from its environment as we can the center of a circle from its circumference.

As the name amphibian implies, frogs are beings between water and land. They are not wholly at home in water (as are fish) and are not fully at home on dry land (as are many reptiles). But they are not "homeless"; they are at home in the in-between. They are aquatic for periods of time and, when on land, retain an affinity to moisture. They are in this sense "moist-earth" beings. This is even true of brightly colored tropical frogs that live high up in tree canopies (following a tendency of many tropical plants and animals to raise their "ground" into the crowns of trees). These frogs lay their eggs in little pools created in crevices or depressions of a tree or in rosettes of epiphytes such as bromeliads, where the eggs stay moist and largely hidden from direct sunlight.

The frog's skin is moist and rich in glands. Some of the most potent animal poisons are produced in the skin of colorful tropical frogs. Poisons in reptiles or insects are usually created in glands within the organism. In frogs the external organ of the skin maintains some characteristics of an internal organ—breathing, drinking, and secreting.

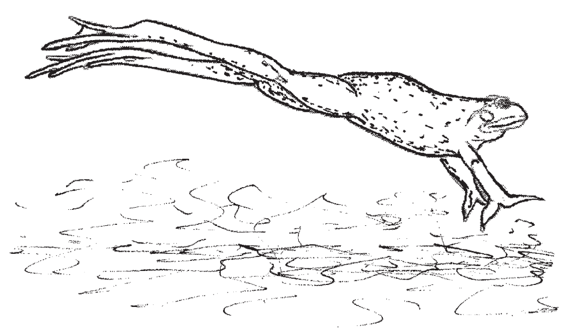


Figure 2. A leaping frog about to land (*Rana esculenta*). (Altered, after Zisweiler 1976, p. 230.)

From this perspective we can see how the so-called external environment of the frog in a sense belongs to or is part of the frog. This attunement is something you can sense almost viscerally in the early spring in the northeastern United States, when the temperature rises and the first rains fall. As part of this change, the enchanting and atmosphere-filling chorus of spring peepers and wood frogs resounds.

Much of what I've discussed so far is true not only for frogs but for the other two groups of amphibians as well: salamanders and the little-known caecilians. What clearly sets frogs apart from these other amphibians is their form and the specific ways of behaving that are intimately connected with their unique bodily configuration.

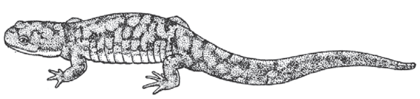
While a tadpole is reabsorbing its tail, it is also developing its long and powerful rear legs. The long intestine of the tadpole shortens dramatically, and the compact body takes shape as the head and body flatten and widen. The muscular rear legs are longer than the body, as the drawing of a leaping frog vividly illustrates (see Figure 2). A frog has a morphology and manner of movement that is wholly different from that of its amphibian relatives—salamanders and caecilians.

Figure 3 shows a selection of different amphibians. Salamanders have a long body with relatively short legs. In some species the body elongates dramatically while the legs become shorter and, in some cases, the rear legs do not develop at all. The caecilians, which are tropical burrowing, worm-like amphibians, have no limbs and a very long body. In contrast to salamanders, they have no tails. Morphologically, amphibians form a spectrum, with rich variation between the short-bodied, limb-dominated frogs at one pole, and the long-bodied, limbless caecilians at the other. And while the dominant sense in frogs is sight, the caecilians are fully or almost blind.

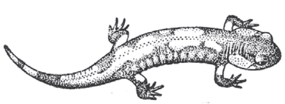
The skeleton reveals in telling detail salient features of frogs. Frogs have the least vertebrae of any vertebrate, and the vertebral column (spine) is very short. Like all other amphibians, frogs have only one short neck vertebra, so that the head attaches almost without separation to the body. But the frog has only eight other vertebra (some species have fewer) in its spine (including one sacral bone), while salamanders generally have 15 to 20 (63 in the long-bodied siren). The skeleton of caecilians consists mostly of vertebrae—between 95 and 285, depending on the species—and they have no tail.

Interestingly, while externally a frog has no tail, it does have one bone—the urostyle (or coccyx)—that corresponds to a tail in salamanders. This long bone develops out of three to four vertebrae that fuse together. It does not extend, however, beyond the pelvis; rather, it is drawn up into the pelvis and is a functional part of it (see Figure 4). Qualitatively this is a revealing characteristic: what would be part of the tail extending behind the body in salamanders or other animals is in the frog one long bone that is incorporated into the pelvis and helps to support and anchor the powerful rear legs. This detail expresses the overall contracted morphology of the frog's body—a contraction correlated with the remarkable expansive development of the rear legs.

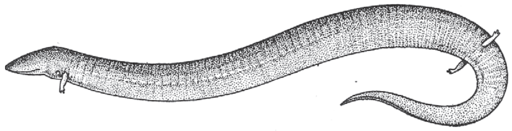
Rana (Frog)



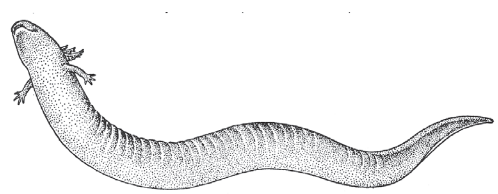
Ambystoma (Salamander)



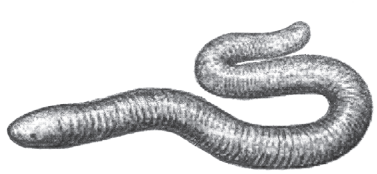
Salamandra (Salamander)



Amphiuma (Salamander)



Siren (Salamander)



Ichthyophis (Caecilian)

Figure 3. Various amphibians; see text. (Different sources; not to scale.)

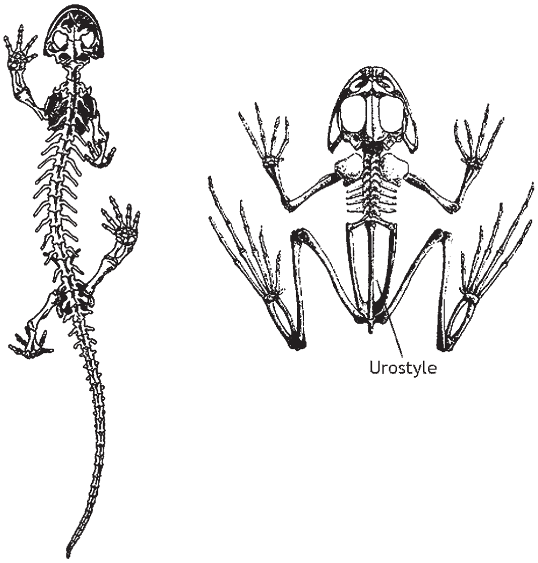


Figure 4. Skeleton of a salamander (*Salamandra*) and a frog (*Rana*).

Now think of the way a frog moves. Sitting with its legs folded close to its body, the frog suddenly and spring-like extends its legs, propelling itself through the air. It cushions its landing with its forelegs and then the rear legs contract again at the sides of the body. Frog leaping is a radical kind of expansion and contraction, morphologically mirrored in the compact body and the long, strong rear legs. Rapid, projectile-like movement also occurs in feeding when frogs use their "well-developed tongues [that] they are able to catapult from their mouths in order to pick up prey" (Duellman and Treub 1994, p. 365).

And when frogs croak, the body wall around the air-filled lungs contracts and forces air through the larynx, which suddenly relaxes and opens. The air streams over the vocal cords and into the mouth, filling the air sack, the skin of which vibrates. The surrounding environment fills with sound. The active animal expands out into the larger world. The chorus of many voices resounds in the spring landscape.

Portrayal

> Any attempt to directly express the being of a thing is fruitless. What we perceive are its effects, and a complete narrative of these effects would encompass its being. We labor in vain to describe a person's character; however, when we draw together his actions, his deeds, a picture of his character will emerge. (Goethe, 1995, p. 158)

Since every organism is a being-at-work, its being as a wolf or frog is not given as a thing. You can't place the "frogness" of the frog next to its liver, brain, heart, and stomach to examine it. You cannot describe it directly; it is not a spatial entity. In this sense Goethe can say that it is "fruitless" to try to express the being of a thing. But that does not mean it does not exist, and it does not mean we must resign ourselves to compiling facts.

The frog as being-at-work is at work in the formation of all its organs, in the shape and proportions of its legs, in the way it feeds. It is present in all its activities and in the relations it engages in. It is in all of these, not as a thing to be found but as effective agency. So how do I come to perceive and present this "no thing" that is certainly not nothing? While there are no simple "steps" in this process, there are different facets that can be understood as a scientific methodology for a "science of beings."

Engaging: As a researcher I carefully study the organism and work to gain an ever better sense of its specific way-of-being. I try to notice and observe: The frog leaping into the pond when I come close; the frog floating with only its big bulging eyes and wide mouth breaking the water's surface; the varied colors of individual wood frogs; the way tadpoles swim. So I attend to the frog. And I do not rely only on my own observations. I also read extensively in the scientific literature about frogs. Many people have dedicated their professional lives to studying myriad aspects of frog life and I draw from their findings and insights.

Freeing: Because much research is dedicated to discovering causes ("mechanisms") and to embedding findings in over-arching theories (for example, evolution through "natural selection") there is a good deal of thought-work involved in trying to discern how findings are influenced by frameworks. I work to free myself from the biases and interpretations that constrict a more open-ended consideration of the phenomena. I do not want to place the facts in the context of a theoretical framework but discover how they place themselves within the organism itself.

Picturing: By going into so many details I can also increasingly lose any sense of the organism's way-of-being and its wholeness. I may lose the forest for the trees. So it takes constant effort to make conscious the connections and relations through which the organism reveals itself. To this end I try to picture what I'm observing or the findings I'm reading about as vividly as possible. I'm not focusing in a narrow way on "why" the frog has this or that or does this or that. I'm not trying to "explain" the frog. It was through vividly picturing the development of a tadpole into the adult frog that I first realized that in a very essential sense it is not correct to say that the adult form develops "out of" a tadpole. Rather, this form is the result of creative activity that wholly re-configures what was tadpole into adult frog.

By staying close to the observed phenomena and connecting the separate observations into a unity that reflects the unity that is at work in the organism, I get a glimpse in thought of its way-of-being. The thought energy others put into theorizing, I put into picturing.

Comparing: The particular way-of-being of an organism stands out all the more when we compare its characteristics with those of other organisms. What it means to be a frog becomes clearer when we let it be illumined by other amphibians (salamanders and caecilians) and then by "neighboring" vertebrates such as bony fishes and reptiles. We cannot understand the frog in isolation; it speaks its reality through its relations to others. We let the different kinds of beings and their characteristics illuminate each other.

Intuiting: When I was in college and dissected a frog, I learned that it had a urostyle. At the time this bone made no big impression on me; unfortunately, it was simply one more part to memorize. In my recent study of the frog the urostyle suddenly lit up. I no longer saw it as an anatomical part but as a crucial member of this organism. I saw through it a quality of the frog: what is in other animals the extensive tail becomes in the tailless frog an internal bony structure that supports the strong leaping legs. This is a form of perceiving meaning in the organism—how the "parts" are truly revelatory of the whole organism. This kind of intuiting is not something you can make happen, as little as you can make a frog appear in a pond. But you can prepare for such insights through all the work described above, so that you are moving in the territory in which connections can show themselves.

Portraying: In a visual portrait, the character of a person shines through the whole presentation and composition—through the way the parts are composed by the artist. He or she has glimpsed this character and seeks to give it artful expression. A scientific portrayal of an organism requires something similar. In portraying, I attempt to depict specific qualities, activities, and relations in such a way that the being-at-work of the frog can show itself to the reader. I can only suggest. As Owen Barfield points out, "meaning itself can never be *conveyed* from one person to another; words are not bottles; every individual must intuit meaning for himself " (Barfield 1973, p. 133; his emphasis). Since meaning is concerned with relations, it can only speak between the lines in the active mind of the reader. Of course, much depends upon the felicity of expression and composition. If I succeed in describing the characteristics of an organism as vividly as possible, and if readers vividly picture what they read, then an understanding of the organism as a being can arise.

When I've completed a portrayal, I am not done and my engagement with the frog is not something that I leave behind. What I have noticed is that after the intense process of working with a particular animal or plant, when I go out and see it in the wild again, my perception is different. A green frog swimming in the pond is much more of a presence than it was before. The forceful and yet graceful kick of the legs, the shimmering green of its head, its bulging eyes—these details speak more strongly. My interest grows and also a kind of elemental joy in moments when I am able to participate in another being's way-of-being. I am more present, and the frog can present itself more fully.

I then experience the truth of Emerson's statement: "It seems as if the day was not wholly profane, in which we have given heed to some natural object" (1983, p. 542). The "natural object" loses its profanity when it becomes a presence—when we have been touched by another being.

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DNA and the Whole Organism

Stephen L. Talbott

Here are a few excerpts adapted from a very much longer article, "From Genes to Evolution: The Story You Haven't Heard." My intention in that article was to illustrate some of the immediate lessons I've gained from the past several years spent studying gene regulation and related topics, and then to shift attention toward the broader implications. And so I made the most systematic effort I have ever undertaken to picture how DNA and genes actually relate to the rest of the organism, and then I tried to show how this bears on our understanding of organisms and their evolution. If we take the picture seriously, we find ourselves with a biology and an evolutionary theory turned "upside down and inside out." The following excerpts contain nothing about evolution, and not much about DNA; they are mostly drawn from various introductory or summary portions of the article. The full text is available at RediscoveringLife.org/ar/2015/genes_29.htm.

You can hardly turn around today without hearing from this or that biologist or philosopher that we have gone beyond old, narrow conceptions of genes (certain DNA sequences) as the makers of organisms. And ours is indeed a time of great and bracing change—change, even, that portends revolution. Yet genes are still almost universally regarded as the true bearers of destiny within the organism, and "genetic" remains an entrenched synonym for "heritable." In other words, genes retain their status as the one intrinsic factor truly definitive for the life of the organism. Implications of the fact that organisms exist and act as wholes remain taboo.

The taboo is not hard to understand, since we can fully acknowledge an organism's agency only by abandoning the materialism and the machine models that have captivated biologists for so long. This is why we see such widespread efforts today to understand this agency by denying it—that is, by tracing and adding together (in "networks" and "systems") local and momentary causal interactions from which the coordinating agent has been excluded.

Some do acknowledge, it is true, that the "system's" behavior cannot be predicted from its parts—cannot, in fact, be decomposed into stable parts at all. But even they, faced with the question where the actual unity and behavior of the organism reside (Who is doing the behaving?) seem reluctant to acknowledge that the organism's coherence is a coherence of intention, idea, and reason operating at the organic level.

The word "agency" may be infiltrating the vocabulary of some philosophers and biologists, but one guesses that they can mention the necessarily implied *being*, or *agent*, only at peril of their career.

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Genes and Cells: Who's Regulating Whom?

Perhaps you are too cold or too hot, hungry or sated, coming down with a flu or recovering from it, lifting weights or resting, thinking hard or yielding to reverie. Perhaps you have a wound that is healing, or have just now suffered a terrible psychological shock, or are concluding an intense lecture to college students. Or perhaps not much has happened at all, except that the sun has moved from the eastern to the western horizon.

Whatever your changing circumstances, the unseen physiological consequences could hardly be more dramatic. The performances of countless cells in your body are redirected and coordinated as part of a global narrative for which no localized controller exists. This redirection and coordination includes a unique choreography of gene expression in each individual cell. Hundreds or thousands of DNA sequences move (or are moved) within vast numbers of cell nuclei, and are subjected to extraordinarily nuanced, locally modulated chemical activity so as to contribute appropriately to bodily requirements that are nowhere codified—least of all in those DNA sequences.

But let's place before our attention a more concrete picture.

In his little book, *The Directiveness of Organic Activities* (published in 1945), British biologist E. S. Russell describes contemporary work on wound healing in the blood-sucking hemipteran bug, *Rhodnius prolixus*. Beneath the hard, outer cuticle of this insect is a single layer of epidermal cells on top of a basement membrane. If you excise a tiny sliver of these tissues, you set in motion a remarkable series of healing processes.

To begin with, the neighboring epidermal cells become activated and migrate toward the edges of the cut, while red blood cells accumulate in the same area beneath the basement membrane. Having congregated at the site of injury, the epidermal cells then spread into the excised area.

In simple cases, where the wound is small and the basement membrane intact, the wound is quickly covered by a few cells that are spread excessively thinly, with cytoplasmic bridges connecting them. As more cells follow these, they become more and more crowded until the normal density is reached, at which point the spreading ceases. After the migration, cell division continues, but mainly in the now-thinned area from which the migrating cells came. As for the cells that spread over the cut, they initially form a layer several cells thick, but the normal one-layer-thick epidermis is slowly restored through selective degeneration of the unwanted cells in the lower layers. Any overcrowding around the margins of the wound resulting from the migration of cells is similarly relieved by the degeneration of superfluous cells.

Rhodnius prolixus

It's good to imagine this elaborately organized, sequential activity in detail. There can be no doubt that we are seeing a norm—the organism's own unique wholeness and integrity—being reestablished:

> The end-state or terminus towards which the process moves is the restoration of the continuity of the epidermis, the replacement of cuticle and basement membrane, the re-establishment of the normal density of nuclei—a complex result, reached through appropriate activities of cells, which are here the agents concerned. These activities are of several kinds. They are behavioral—as shown in the active migration and spreading of the epidermal cells. They are physiological, as in the secretion of new cuticle. They are "morphoplastic," as in activation and cell division; cells also degenerate where they are superfluous or unwanted.

Most interesting, however, is what happens when conditions are varied, and the same norm is restored, but by a very different route. For example, using heat, it's possible to destroy a group of epidermal cells without injury to the overlying cuticle. In this case there is little migration toward the burn margin from surrounding areas. Rather, the existing cells at the immediate margin begin to fill in over the layer of burned cells—and they do so through multiplication within this zone of spreading rather than through migration from the periphery.

Compare this with the incision, where the injured area was filled to "overcrowding" by migration, with subsequent die-off of excess cells in the injured area. And whereas, with the incision, cell multiplication occurred in the more distant regions from which migration occurred, in the case of the burn, multiplication takes place in the injured area.

It seems that a general truth of healing processes is that they culminate, as far as possible, in the restoration of normal form and functioning. Depending on conditions, there can be a remarkable variation of means toward this end.

The point is not at all that there are no lawfully connected physical processes every step of the way, but only that the immediate causal factors are caught up in a larger pattern that governs them. No study of well-behaved local interactions shows us why those interactions are coordinated in the plastic, goal-directed, context-sensitive manner we observe—a manner that enables them to reach the same end by different pathways, depending on the circumstances encountered.

When we look at pattern in this way rather than adding together separate physical causes, we see a logic of the pattern as such, not a necessity for any particular causal sequence.

It is, of course, a long way from the simplest possible injury of *Rhodnius prolixus* to a complex wound of *Homo sapiens*. Here is a general description of the kind of thing that goes on when you or I suffer the "assaults" of a surgeon—wounds typically of a sort that our species never before encountered during its evolutionary history. It comes from another British biologist, Brian Ford:

> Surgery is war. It is impossible to envisage the sheer complexity of what happens within a surgical wound. It is a microscopical scene of devastation. Muscle cells have been crudely crushed, nerves ripped asunder; the scalpel blade has slashed and separated close communities of tissues, rupturing long-established networks of blood vessels. After the operation, broken and cut tissues are crushed together by the surgeon's crude clamps. There is no circulation of blood or lymph across the suture.
>
> Yet within seconds of the assault, the single cells are stirred into action. They use unimaginable senses to detect what has happened and start to respond. Stem cells specialize to become the spiky-looking cells of the stratum spinosum [a layer of the epidermis]; the shattered capillaries are meticulously repaired, new cells form layers of smooth muscle in the blood-vessel walls and neat endothelium; nerve fibers extend towards the site of the suture to restore the tactile senses . . . These

> phenomena require individual cells to work out what they need to do. And the ingenious restoration of the blood-vessel network reveals that there is an over-arching sense of the structure of the whole area in which this remarkable repair takes place. So too does the restoration of the skin. Cells that carry out the repair are subtly coordinated so that the skin surface, the contour of which they cannot surely detect, is restored in a form that is close to perfect. (Ford 2009)

It is well to reflect diligently upon that phrase, "an over-arching sense of the structure of the whole area." It is not a phrase that biologists today know what to do with. Who or what possesses this sense? And if "sense" is the wrong word, what is the right one?

Cells Caught Up in an Intentional Whole

Think concretely about that surgical wound. You're a nearby epidermal cell, and you need to migrate. In which direction? When do you stop? And how do you reorganize all your constituent elements so as to bring yourself into movement—movement away from the place where you've long been settled?

Or you're a nerve cell, and you need to participate in the extension of a nerve fiber. Again, in which direction, and by means of what sort of mobilization of all your internal processes?

Or perhaps you're a stem cell and you need to begin a process of differentiation. But differentiation into what sort of other cell? And how do you go about a radical change in who you are? If change is going on everywhere around you, what gives anything its specific "operational advice"?

Everything needs to be accomplished in the right sequence, and in harmony with everything else going on—all this amid what looks for all the world like a chaotic disaster scene. How are we to imagine the ultimate and nearly incomprehensible *coherence* of the larger picture?

Now, rare is the biologist today who will hear such questions without thinking: "He is trying to suggest that there is no physical explanation adequate to these living processes. So he believes there must be some sort of vital force or miraculous guidance to make things happen."

But this misses the mark entirely. The physical continuity of the entire scenario is unquestioned. Russell, for example, is always looking for immediate physical interactions. In *Rhodnius prolixus*,

> observation shows that the migrating cells are specially attracted towards areas containing dead and damaged cells, and this suggests that the stimulus to activation is provided by chemical substances produced by the injured cells, and that migration towards the wound is a "chemotactic" response to these substances.

Yet Russell does not confuse this physical continuity of local interactions with what he somewhat awkwardly refers to as the "directiveness" of the larger storyline in which these interactions are caught up. It's a confusion that biologists today almost universally consent to.

It's not hard to observe one's own reaction to the statement that migrating cells are activated and directed by a chemical gradient resulting from the death of nearby cells. "Oh, that explains it." But what has happened with this "explanation"? The entire picture of cell migration—a complex mobilization of the cell that biologists have barely begun to understand—has been reduced in thought to an object here and an attractant there. It's an almost mechanical schema—hardly problematic at all! We might as well be thinking of two rigidly interlocking gears, given that we have blocked from our minds the crucial thing: how do all the physical interactions adaptively cohere as part of meaningful, "directive" processes, such as wound healing?

* * * *

DNA as Part of a Whole

(This section contains a few summary comments relating to material in the original article.)

A decisive problem for the classical view of DNA is that "as cells differentiate and respond to stimuli in the human body, over one million different proteins are likely to be produced from less than 25,000 genes" (de Almeida and Carmo-Fonseco 2012). Functionally, in other words, you might say that we have over a million genes. But here the word "gene" cannot refer to a defined sequence of genetic "letters." It must refer, in the first instance, to certain characteristic, context-dependent activities of cell and organism—activities in which DNA figures along with innumerable other players.

A useful way to begin thinking about the reality of genes is by overcoming the false picture of DNA as an idealized, geometric configuration. Since Francis Crick and James Watson's elucidation of the structure of DNA in 1953, biologists have been "in denial," according to *Nature* columnist, Philip Ball. "That beautiful double helix, with its genetic information written into the spiral staircase of paired nucleic-acid bases, offers such an elegant picture of the chemical principles of life and inheritance that everyone fell for it."

The Genome in Dynamic Nuclear Space

A few comments from the literature:

- "The dynamic spatial organization of the nucleus both reflects and shapes genome function . . . We now have a picture of a genome that is 'structured,' not in a rigid three-dimensional network, but in a dynamic organization [that] clearly changes during normal development and differentiation" (Fraser and Bickmore 2007).
- Researches have revealed "the astounding degree to which our genome . . . appears to be dynamically utilized for the purposes of gene regulation" (Joanna Wysocka, in Dekker, Wysocka, Mattaj et al. 2013). Of course, the question most immediately implied doesn't get asked: utilized by whom, or by what?
- Although the researchers' first impulse was to find in chromatin modifications (such as histone tail modifications) another "simple code," it eventually became evident, according to geneticist Shelley Berger of Philadelphia's Wistar Institute, that "a more likely model is of a sophisticated, nuanced chromatin 'language' in which different combinations of basic building blocks yield dynamic functional outcomes" (Berger 2007).
- "What was previously known as junk DNA in fact appears a regulatory jungle. In order to understand the laws of the jungle, linear information must now be converted into spatial relationships" (Splinter and de Laat 2011).
- Indeed, the almost exclamatory recognition that "Genomes are incredibly dynamic" (Chalker and Yao 2011) in both space and time has become commonplace today, even if it still seems to surprise many. But the appropriate questions have scarcely been addressed as yet. No one would argue that DNA itself is "incredibly dynamic," for it is just about the most inert substance in the cell, at times approaching an almost crystalline state. It is the cell as a whole that brings our DNA and chromosomes into the movement and directed activity through which they are made to serve the needs of digestion, muscular exertion, sensory perception, and all our other biological functions.
- "The sequence of our genes are [sic] like the keys on the piano; it is the context that makes the music" (Bissell and Hines 2011). Except that the raw sequence does not even contain all the keys; let's say: just the white keys. The flats and sharps, without which the music would lose its savor, are provided by DNA methylation, RNA editing, and more.

The image Ball refers to has become a dominant icon of the modern era, channeling the imagination along the alluring lines of its own geometric perfection. Yet its ubiquity and influence is matched only by its falsehood. For "when we come face to face with DNA in the cell," writes Ball, "it's like meeting a movie star whose airbrushed publicity photos don't look at all like the real thing. You would barely recognise Crick and Watson's perfectly-formed molecule in the tangled, twisted and bent spaghetti that is stuffed inside the nuclei of our cells" (Ball 2008).

In living cells the double helix is "distorted" in every possible way—due, among other things, to the endlessly morphing intricacies of *chromatin,* the massive, ever-changing, protein–RNA complex engaged with DNA in a mutual embrace. We can only assume that this plastic receptivity of the double helix is part of its gift to the life of the organism.

And it is indeed the *life* that we are witnessing at every point and in every detail. The organism manages its DNA with a wisdom, thoroughness, efficiency, and expertise beyond all current possibilities of comprehension. For example, the subtleties of DNA replication rival those of gene transcription [which the main article focuses on] and are, in fact, intimately woven together with processes of gene regulation. But the organism's intentions and activities relative to its DNA are evident on other fronts as well.

There is, for example,

- the play upon chromosomes of mechanical forces from throughout the cell and beyond;
- the infinitely varying electrical forces between DNA and the diverse elements of the dynamically changing chromatin it is bound up with;

- the all-important (if transient) "mooring" contacts between DNA and the more or less stable structures of the nucleus, especially the nuclear envelope;
- the positioning of different parts of the genome in the nucleoplasm relative to significantly gathered concentrations and mixtures of molecules participating in gene expression;
- the looping of chromosomal regions on various scales in order to bring the right "team players" together;
- the formation of all sorts of unusual DNA structures, including three- and four-stranded structures, which play a role in gene regulation—

all this and much else contributes to the cell's management of gene expression, quite apart from the more routinely recognized players: interacting transcription factors, co-activators and co-repressors, promoters and enhancers, splicing factors, and all the rest.

The organism's expertise in managing its DNA cannot be questioned. It is capable of inserting new sequences in DNA, deleting old ones, moving them from here to there, exchanging them between chromosomes, and so on. Even the repair of breaks in DNA is not always merely repair. The cell can make such events the occasion for its own remodeling of the genome. In fact, it is continually *initiating* single- and double-strand breaks, then stitching things back together—a frequent enough requirement, if only to facilitate the organization, disentanglement, and proper physical characteristics of the DNA (such as the degree of double-stranded "twist"). To get a picture of the challenge in simply preventing hopeless entanglement, consider that the amount of DNA in a human cell nucleus is equivalent to twenty-four miles of extremely thin, double-stranded string crammed into a tennis ball.

Sometimes individual genes or sections of a chromosome are duplicated in certain cells. But genome remodeling goes beyond this. Megakaryocytes (cells involved in platelet production in bone marrow) have up to 128 copies of the entire genome; hepatocytes (liver cells constituting some 3/4 of the liver's mass) typically have 4 to 8 copies; trophoblast giant cells in the embryonic outer layer may have up to 1000 copies; and cardiomyocytes (heart muscle cells) usually have 4 copies of the genome. In some cell types such as skeletal muscles, there are many separate nuclei in a single cell, each with its full complement of DNA.

The still-routine statement (I have sometimes acquiesced in it myself) that "all the cells in our body have the same DNA" has been found to fall further and further from the truth. According to a recent report, "perhaps the quantity of nuclear DNA content in human cells is best viewed as a distribution of values" rather than as a single value. New analyses are suggesting that "systematic variation in nuclear DNA content is a more ubiquitous phenomenon in human cells than was previously appreciated" (Gillooly, Hein and Damiani 2015).

Let me then state one lesson clearly: *the organism knows what it is doing* with its DNA, as with all its molecular activities. Yet this living, active, and governing wisdom that we confront face to face in every organism seems to threaten a kind of theoretical paralysis in biologists, who have therefore long since learned to ignore it as they pass by, whistling innocently.

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Upcoming Events

"The day is coming when a single carrot freshly observed will set off a revolution."

– Paul Cezanne

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