In Context

The Newsletter of **The Nature Institute**

#42

Fall 2019

Dear Friends,

One problem we constantly come up against in our work here at the Institute has to do with the differences between our own human experience and the meaningful activities we try to describe in other organisms. Those activities include purpose-like behavior and the cognitive aspects of perception. How can we characterize such activities in a paramecium or elephant without reading, or seeming to read, features of our own behavior and perception into organisms very unlike us?

In her article on the restoration of bald eagles in this issue, Henrike indirectly alludes to the problem when she remarks: "It is not so easy to be aware of and concerned about the disappearance of creatures less conspicuous than the emblematic bird, such as many amphibians, reptiles, fish, insects, spiders, song birds, and more." What are the reasons that we come to value and rally behind certain creatures, while we attend to others—regardless of their ecological significance—much less?

Craig faces the problem of anthropomorphism in one of its more extreme forms when he asks, "Do Flowers Hear Bees?" — except that in this case we are not speaking of anthropomorphism proper:

> I've noticed in the literature a tendency to animalize plants as a means of giving them more credence as "substantial" beings on earth that we should be more aware of and care for. But this is not at all necessary. Plants are remarkable creatures in their own ways. We don't need to analogize them with animals, which scientists do when they refer to "neurobiology" in plants.

And Steve comes up against this problem in a yet different way when he discusses the "purposive" character of life. In his feature article, he writes that the activity of proteins in the human body is "graceful, artistic, purposive, and meaningful." This is not language typically used when describing molecules, and yet — given all the research findings — it seems much more suitable than all the talk of "molecular mechanisms" that are supposed to make life happen. The mechanistic language distorts our picture of living processes.

At the Institute our struggle to find the right descriptive language for the living qualities of life is ongoing. The wrestling with ideas and language sometimes leads to heated (if also friendly!) debates among ourselves. We don't expect the issues to go away any time soon.

To perceive phenomena carefully and then to work to articulate experience in adequate ways is something we focus on during our year-long foundation course, which you can read about in this issue. It is heartening to experience the willingness of participants to challenge accepted paradigms and to strive to bring phenomena to expression in fresh and context-sensitive ways. This too is ongoing work, and we are glad that through the course, participants and teachers alike have the opportunity to stretch their abilities in the effort to let life manifest itself more fully.

Craig Holdrege — Steve Talbott

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The Nature Institute

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The Return of the Bald Eagle

Henrike Holdrege

Living in upstate New York not far from the Hudson River at the edge of the Taconic Mountains, I have the good fortune to occasionally witness the presence of the bald eagle in our region.

On my sporadic train rides to and from New York City along the Hudson River, I rejoice when I am able to find a window seat on the river's side. While most other passengers are engaged with their screens, I watch the scenery outside: the sky and its clouds, early morning fog rising over the water, the tide coming in or going out, the waves or patches of smoothness of the water, mirror images, the spreading of invasive plants at the river's edge, the many species of birds that live near or by means of the river. The river valley is beautiful at all times of the day.

And I watch for bald eagles. Sometimes I count how many I see. On a recent trip this summer, coming from New York City at midday, I had four sightings: one bald eagle was sitting low, close to the water's edge; a juvenile bird was flying to a high treetop on which an adult eagle was perched; and a fourth eagle was situated on what appeared to be a nest on a steel structure in the river. While the train rushes by, I catch these glimpses.

I sometimes see bald eagles closer to my home. Once a bald eagle was feeding on the carcass of a deer that had been killed near our house by a car. With binoculars, we observed it from our windows. Or I saw a bald eagle flying over The Nature Institute when we were doing outdoor studies during a summer course. We once watched a group of eagles feeding on a carcass in a field, among them juveniles that lacked the white of head and tail. Some were actively feeding, others were perched in the high trees bordering the field. And we have spotted bald eagles on our canoe trips in the Adirondacks and Catskill Mountains.

During one of my train rides, I learned that there was a time, a period of over hundred years, when there were no bald eagles nesting in the Hudson Valley region. In fact, there was a time when not one pair of bald eagles was successfully breeding in all of New York State. Nationwide, in the contiguous United States, the bald eagle was on the brink of extinction.

The disappearance of this bird from our lands, and its subsequent recovery, is a story to learn from, a story of warning and hope.

Here are numbers and dates: Along the Hudson River, after 1890, no breeding pairs of bald eagles were sighted until 1997. So for more than a century, bald eagles apparently did not breed in the river valley where once they lived freely and thrived. In New York State, in 1970, one active but unproductive pair was found. In the contiguous U.S., in 1963, there were fewer than 500 breeding pairs. In 1973, the bald eagle was listed as an endangered species under the federal Endangered Species Act.

What brought about their decline?

There were three main causes. First, the bird was decimated by human predation for various reasons, or for no good reason at all. Second, the bird lost its habitat due to land settlement and agricultural development. It cannot live without clean air and water, ample food supplies, and large, undisturbed stands of trees. The third factor was contamination of the environment by toxic substances.

For example, after World War II, the insecticide DDT was widely and indiscriminately applied in the United States. Land was sprayed with DDT from airplanes. In 1962, in her book *Silent Spring*, Rachel Carson was the first concerned citizen and scientist who drew public attention to the consequences of the use of DDT. One such consequence was that the egg shells of birds ingesting DDT became brittle and broke before a mature fledgling could hatch. The higher one looked in the food chain, the worse the problem became — and the bald eagle lives at the top of the chain. DDT was banned from use in the United States in 1972, ten years after Rachel Carson's book was published, and one year before the eagle was listed as an endangered species.

After so long a period of no bald eagles breeding in the Hudson Valley region, what brought them back?

In 1976, New York's Department of Environmental Conservation began a program of repopulation. In twelve years, biologists captured 198 nestlings of bald eagles, mostly in Alaska, and brought them to New York. They hand-reared them, moved them to suitable habitats, and fed them while the birds accustomed themselves to the new place. When the young eagles could fly, they were released.

In 1989, there were ten nesting pairs in New York State. In 1997, a nesting pair produced the first fledgling in the Hudson Valley, apparently after more than a hundred barren years.

It took the joint efforts, the perseverance, and the resources of many institutions, agencies, and concerned citizens to bring the bald eagle back to the Hudson Valley. A remarkable cooperation took place between various organizations, including the U.S. Military Academy at West Point, Greenway Conservancy, the Hudson River Foundation, the National Audubon Society's "Constitution Marsh," the Audubon Center and Sanctuary, New York State's Hudson River National Estuarine Research Reserve, the Palisades Interstate Park Commission and its Bear Mountain State Park, and the U.S. Fish and Wildlife Service.

In addition to the repopulation efforts, land was purchased for conservation purposes. And so the ban of DDT, along with all the environmental protection measures, allowed the bird to come back.

The numbers continue to increase: in New York State, in 2014, there were 254 nesting pairs; in 2017, there were 323 nesting pairs. On August 9, 2007, the bald eagle was removed from the federal list of threatened and endangered species, where it had been listed for 34 years. Nationwide, the US Fish and Wildlife Service reported in December, 2018, that the number of nesting pairs in the contiguous United States was 9,789.

The caring for the bald eagle in the Hudson Valley region has not ended. As the New York State Department of Environmental Conservation explains on its website: "The apparent return of the bald eagle to the Hudson River does not mean that conservation practices can end … Increasing human activity, chemical/toxic contaminants and habitat loss must be monitored and controlled if we want to encourage the eagle population on the Hudson."[1]

It is not so difficult to become aware of the disappearance of a bird as large and as magnificent as the bald eagle. However, we could have remained oblivious to its threatened extinction. Today one can be grateful that the alarm was sounded, that the life-threatening conditions were studied and understood, and that action was taken.

With the bald eagle's return and with the restoration of its required habitat, countless other mammals, insects, birds, and fish were also given a habitat. Large enough areas of undisturbed forested land as well as unpolluted rivers, estuaries, and wetlands allow an abundance of other larger and smaller creatures to thrive.

It is not so easy to be aware of and concerned about the disappearance of creatures less conspicuous than the emblematic bird, such as many amphibians, reptiles, fish, insects, spiders, song birds, and more. For example, from Europe and around the world we hear about dwindling populations of butterflies, moths, native bees, wasps, and beetles. When I drive by the many lawns and gardens that look well-kept but are rather sterile and do not support much wildlife — but rather eradicate it through the use of pesticides, herbicides, chemical fertilizers, and the choices made in planting trees, shrubs, flowering plants, and grasses — I sense the responsibility that we all carry in regard to our fellow creatures. This is especially true for those of us who are given a piece of land to own or care for.

The story of the bald eagle's return to the Hudson Valley region teaches us some lessons. We have learned to value the presence of the eagle at the brink of its extinction. We have learned that destroying its habitat and degrading the environment makes the bird vanish. We also learned how much it takes and how high the costs are when we have to undo what in a human-centric way was done unwittingly, carelessly, or worse.

Creatures on earth will remain with us only if we give them space to live, if we do not destroy their species-specific habitats and their food resources. The result of all conservation and restoration efforts, however — if they are successful — is a joyful one.

1. Source: https://www.dec.ny.gov/animals/9382.html

Do Flowers Hear Bees?

Craig Holdrege

In a recent course at The Nature Institute we spent time each morning for a week observing wild chicory (*Cichorium intybus*). Its flower heads open with the brightening of morning; if it remains cloudy, the flowers hardly open at all. The flowers orient themselves towards the sun and move with the sun during the course of the morning. They close and wilt by the afternoon. The way they unfold and bend their flower stalks is an expression of their connectedness with the sunlight. Many other flowers are also attuned to the light of the sun. The sunlight belongs to their lives.

Beach evening primose (*Oenothera drummondii*) in Israel

Similarly, the lives of insects and flowers interpenetrate. Insects gather nectar and pollen as food and in the process pollinate the flowers, allowing them to form fruit and seeds. Nearly ninety percent of plants rely on animals (mainly insects) for pollination.

Recently, an Israeli research team made a fascinating discovery.[1] While it is well known that flowers respond to light, touch, or airborne substances, they wanted to know whether flowers would respond to sound. After all, insects make buzzing sounds with their wings when they fly to and from flowers. So the researchers recorded the buzzing of a bee and replayed the sound in close proximity to numerous flowers of an evening primrose (see photo). In other words, they mimicked the sound of bees hovering around flowers.

They then measured the sugar content of the nectar in the flowers (from which the nectar had been previously evacuated) and found that three minutes after exposure to the buzzing sounds the flowers produced nectar that was sweeter than before. Their nectar was sweeter than in controls that were subject to no sound at all or to high frequency sounds (bee buzzing is a low-frequency sound).

The researchers also observed that the flowers *vibrated* when exposed to a recording of bees buzzing. So the question arises: in what way might the vibrating of the flowers be connected with the production of sweeter nectar? Whatever the connection may be, it seems clear that the buzzing sound in some way belongs to the environment of the flowers, which means there is a connectivity between the two organisms via sound.

Does this mean flowers can hear? No. We don't say flowers are seeing the brightness of the sun, or smelling airborne scents. Nonetheless they are responsive. They are in connection with multitudinous qualities in the world. And when those qualities change, they can change in a way that is meaningful in their life and in the lives of those beings with which they are connected.

There is much research today that falls under the heading of "plant intelligence" or "plant neurobiology." Thanks to this research, a wealth of phenomena have become better known that show how wisely and actively the plant engages with its environment in countless meaningful ways. But there is a danger in using terms that suggest that plants have animal- or human-like intelligence. If the term "plant intelligence" is used to refer to their inborn connectedness with the world that allows them to flexibly relate to changing conditions, that's fine. If the term is used to imply that plants have a kind of centered consciousness through which they feel and experience in the way of a deer or mouse, then we're dealing with speculation that is not based on careful observation.

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Our Foundation Year Program

This past summer was a time of lively activity at the Institute. In June, eighteen students joined us for the opening two-week intensive of our 2019–2020 foundation year course. Then, in July, we came together with the seventeen students from our first foundation year course (the 2018–2019 cohort) and brought that work to a close with a final two-week session.

Participants, from young to old, came from differing backgrounds; there were teachers, professors, writers, graduate students, scientists, naturalists. Working together and sharing with others during the year and in the intensives was crucial. A mother who homeschools her children stated that "having the time and guidance to go through, practice, and see the efficacy of this work has been such a gift, and was made all the more real and meaningful by having a varied community with which to experience it."

We were excited to see that this program has become a significant way for people to deepen not only their understanding of Goethean Science, but also their practice of it.

It is important that the intensives are practice-based — lots of observing, individually and in groups; dialogue about texts in small groups; reflections on method that relate directly to the experiences we've had together; artistic work (mainly working in clay) to engage in the process of forming and transformation. In this way, participants experience and struggle with the actual doing of participatory, phenomena-based science and don't just hear about it from teachers.

Each student is asked to carry out an independent, observation-based research project during the year in between the two intensives. While it is clear that this is no easy task — given the full lives people lead — those who were able to persevere found that the project was essential for them to ground the approach in their own work. A young science teacher who studied an oak tree and its co-inhabitants during the year remarked, "My understanding of what it means to know something has changed. It is more abut perception and the work with the imagination, based in the senses. There's a doorway through which the world becomes more beautiful. It's a re-connecting. I see a way and a process in which I can work in this direction."

Eleven of the participants from the first course gave engaging presentations about their independent research projects, which included the study of a number of different tree species, wild flowers, granite, shadows, sky colors, and medicinal plants.

We will begin a new year-long course in July, 2020. The first intensive for this course will run July 13–25, 2020, and the course will conclude with another intensive July 12–24, 2021. In between, participants will carry out independent research projects, while also studying and discussing selected texts related to phenomena-based science. For more information or to register, visit our website. Registration deadline is February 15, 2020. Space is limited, so we encourage you to apply early.

Below we share a few student comments about the courses:

[What has changed for me during the intensive?]

"Well. Everything. I saw more shades of sky yesterday than I have words for by far, more colors and quality of illumination than I knew existed, and, in general, have smashed my one-size-fits-all categories of things into an inexhaustible supply of the knowable."

– Business owner and participant in second foundation year course

[What has changed for me during the intensive?]

"My attention to detail, awareness of the process of perception itself, my faith in a whole range of phenomenological methods that I either did not know of or was not confident/patient enough to practice before this, and finally my trust in my own visceral experience as a resource I can use to guide inquiry."

– Dual Ph.D. candidate (informatics and cognitive science) and participant in second foundation year course

"In part, the value of this course (for me) has been the change from a more intellectual appreciation of Goethean science to experiencing [it] in a conscious, lived way. Having the luxury of enough time here to thoroughly make and review observations, and to relate them directly to ideas from readings, or experiences of the instructors, has been essential for that metamorphosis. The identification and modification of habits (of thought and action) takes time and repetition. Similarly, doing an independent project was an indispensable component. Through living with a phenomenon (the linden tree) for many months I came face to face with many of the habits that were obstacles to a 'fluid way of perceiving and thinking' and had to confront them directly. I am pleased and satisfied with the progress I made so far as a result, and more clearly recognize areas that need continued work."

– High school science teacher and participant in first foundation year course

Working with the Human Evolution Kit in Egypt

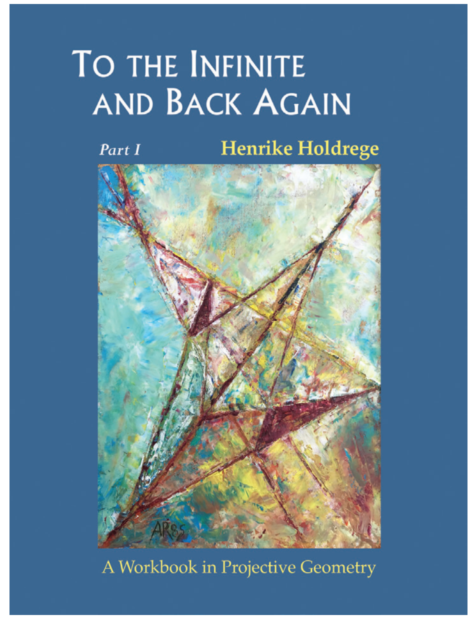
We recently received an email from Axel Ziemke, PhD, a Waldorf teacher from Germany. He had just finished teaching seminars on Goetheanism and Evolution to teachers and university staff at Heliopolis University for Sustainable Development in Cairo, Egypt. Heliopolis was founded in the last ten years as part of the SEKEM organization. SEKEM is a dynamic and prosperous initiative for holistic and sustainable development, which includes many farms, businesses, schools, and a medical clinic. Axel had used Craig's human evolution kit to work with the teachers, and in his email he reported back to us with some pictures and a short description of his experience. Here is what he wrote:

The focus of the seminar courses is both the teaching methods and the topic itself. In both respects the human evolution kit was really great. In Egypt, teaching is traditionally a monologue by the teacher; with the kit it was possible to show how students can be activated and discover things for themselves. Concerning the topic — Egypt is an Islamic country and human evolution is not really an accepted topic. Of course there were very open-minded people, but many of them were not really ready to accept the fact that humans and monkeys could have common predecessors. Of course, I try to build bridges between the Koran and science (and, in fact, Goethe with his affinities to Islam is therefore a beautiful point of reference), but your kit was also very helpful there and has perhaps initiated a rethinking of these questions. In fact, all of the students were very interested.

Cheers from Egypt,
Axel

New Publications — In Print or In Process

A new book by Henrike. This summer we published Henrike Holdrege's *To the Infinite and Back Again — A Workbook in Projective Geometry, Part 1.*



Richly illustrated, this workbook is a practice-oriented introduction to projective geometry and its major theorems. The essential concepts of the infinitely distant elements — points, lines, and plane — that distinguish projective geometry from Euclidean geometry are carefully introduced. Readers are encouraged to engage with the subject through their own drawings. The numerous exercises that often build on each other foster clarity of thought and cultivate our power of exact imagination. As a fruit of Henrike's many years of teaching, the book is intended for self-study by the lay-person. It is also a rich resource for high school and college math teachers.

In working through the exercises, we learn to think transformatively and we experience a beautiful thought world in which ideas weave, grow, and metamorphose. We learn to think the mind-expanding concept of the infinitely distant, a concept that opens up whole new ways of understanding. We begin to see finite forms in a larger context when we conceive them in relation to the infinite.

You can find more information and order the book on our website or by contacting us by phone or email.

New chapters on organisms and their evolution from Steve. A book-length project, now with the revised and still tentative title, *Evolution As It Was Meant To Be — And the Living Narratives That Tell Its Story*, continues to be the main focus of Steve's work. You will find one of the more recently completed chapters — "Our Bodies Are Formed Streams" — as the feature article in this issue of *In Context.*

The first half of the book, which includes this particular article, is titled The Life of Organisms. The second part, Extending the Organism's Story: Toward an Evolutionary Narrative, begins with another recently completed chapter, "Let's Not Begin with Natural Selection." Everything associated with the project, including the ten or so chapters already written, is freely accessible online at http://natureinstitute.org/txt/st/bk.

Steve regards his overall work on molecular biology, genetics, and evolution over the past ten years as mere preparation for this current project. The largest challenge lies in the fact that the book covers such a wide range of highly specialized topics. Due to the rather massive and continuing research required by this variety, he estimates that the conclusion of his effort probably lies at least a year and a half away (if "conclusion" can ever be the right word for work dealing with many fields of inquiry currently being transformed by almost violent rates of change).

Steve hopes that interested readers will follow along with him in the online publication of these chapters.

The culmination of Craig's popular whole-organism studies. Every animal on earth has its own unique character — the slow sloth, the burrowing mole, the towering giraffe, the huge but flexible elephant. Each of the portrayals in Craig's new book (which will be published next year) is self-contained and illuminates the way of being of that animal. Readers will learn fascinating details and, importantly, see how all the features of an animal are interconnected, revealing the animal as a whole. They will also learn how each animal is intimately interwoven with the larger context that supports its life, a context that it also actively influences. Speaking of the book, Craig writes:

> I have increasingly come to see that animals are beings who actively orchestrate their existence. You find dynamic and flexible orchestration in the most basic physiological processes, in the plasticity of development, in the maintenance of form, and in the malleability of behavior in relation to an ever-changing environment. Each type of animal is not only unique, but also intersects with other animals, plants, and the earth. Together, they weave a cohesive yet evolving world.

The book is refreshingly uncommon in its approach, although it has roots in the more general tradition of holistic biology and phenomenological science going back to the poet and scientist, Johann Wolfgang von Goethe. It is neither a popular natural history of animals nor a specialized treatise on animal biology, but rather opens up an integrative understanding you are unlikely to find elsewhere. Craig writes, again:

> We do great injustice to animals when we depict them as evolutionary survival strategies, or project our all-too-human characteristics onto them. With the open-ended question, 'Who are you?' and the will to let the animals themselves be my guide, I avoid the mechanistic and anthropomorphic interpretations that unfortunately take hold of so much writing about animals. My aim is to give voice to animals as beings rich in qualities that make them distinctive and irreplaceable.

At Home

• This past summer The Nature Institute twice offered two-week intensives as part of our ongoing foundation year programs, *Encountering Nature and the Nature of Things*. You can read about these programs on page 6–7.

• At the end of September, Henrike gave a talk at the Institute entitled "The Drama of Knowing – Connecting or Disconnecting?" She discussed the phenomena-based scientific approach that the Institute has practiced for the last twenty-one years and it's importance for the world today.

• Following Henrike's talk, Henrike and Craig led a day-long workshop on "Transformation through Nature Study" where they presented participants with a number of different natural phenomena. They also looked at the transformation of capacities that can happen through such direct experience — what Goethe points to with his expression "a new organ of perception."

• In October we were joined by board member Jan Kees Saltet and his wife Polly Saltet. Jan Kees gave a talk on Emily Dickinson, exploring through her work the path of meeting nature and soul without sentimentality but with earnest commitment, and Polly framed the evening with artistic movement in eurythmy.

Still Ahead

• In November, Craig and Henrike will again be traveling to Florianopolis, Brazil, to teach for two weeks. This will complete the second year-long program that they've now offered there, a course entitled "Seeing Nature Whole — Foundations of Goethean Science." The course is hosted by the Associação Sagres, a center for adult education.

• In January Craig travels to Melbourne, Australia. He will give a series of keynote talks on "From Encounter to Insight: Pathways of Experience in Education" at a week-long professional development conference for Waldorf high school teachers. He will also give a multi-day class on "A Delicate Empiricism: Practicing Goethean Inquiry." After the conference he will lead a public weekend workshop in Melbourne on the topic "Finding Our Humanity: Freedom and Our Responsibility for the Earth."

• In January and February, 2020, Henrike and Craig will work for three afternoons with the students in the local Alkion Center's teacher education program. The focus is on Goethean methods.

• "The Living Earth" will be the topic of our winter intensive February 16–20, 2020 (see the back cover of this issue).

• Next June and July we will conclude the current year-long foundation course (2019-2020) and begin another one (2020-2021). Read about the progress of this program on page 6–7 and consider joining us for the next course!

Our Staff

Linda Bolluyt, The Nature Institute's office manager since 2011, retired last May. In her position she carried out countless tasks with equanimity, friendliness, and an unceasing willingness to do what needed to be done. She was an integral part of The Nature Institute for eight and a half years, and we were sad to see her go.

Before leaving, Linda worked closely with her successor, Kristy King, to help her get to know the many tasks she is now taking on. Kristy has been with us since May and it has been a great pleasure to get to know her and begin our work together.

So, we send our deep thanks to Linda for all her years of colleagueship, and enthusiastically welcome Kristy to the many years of colleagueship to come!

Kristy King (left) and Linda Bolluyt

Thank You!

Last spring's $5000 challenge grant appeal yielded over $12,000 in support! Our thanks not only to the Nature Institute friend who offered the challenge, but to all you who responded — and also to all who contributed financial support, goods and services between April 1 and September 30, 2019.

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Our Bodies Are Formed Streams

Stephen L. Talbott

This is a chapter from a book-in-progress tentatively entitled Evolution As It Was Meant To Be – And the Living Narratives That Tell Its Story. *The currently available chapters are at http://natureinstitute.org/txt/st/bk. Some of the chapters referred to here are not yet written.*

In this materialist era, we like our reality *hard* and our truths *weighty* and *rock solid*. We may accept that there are states of matter less substantial than rocks, but in our imaginations we turn even fluids and gases into collections of tiny *particles* more or less closely bound together. Similarly, in our reconstructions of physiological processes, *material structures* come first, and only then can movement, flow, and meaningful activity somehow occur.

How, after all, can there be movement without *things* to do the moving? (It's easy to forget that energy, fields, and forces are not things!) Ask someone to describe the circulatory system, and you will very likely hear a great deal about the heart, arteries, veins, capillaries, red blood cells, and all the rest, but little or nothing about the endless subtleties of circulatory *movement* through which, for example, the structured heart first comes into being (see Chapter 6, "The Unmechanical Heart").

Yet there is no escaping the fact that we begin our lives in a thoroughly fluid and plastic condition. Only with time do relatively solid and enduring structures precipitate out as tentatively formed "islands" within the streaming rivers of cells that shape the life of the early embryo. As adults, we are still about seventy percent water.

One might think quite differently based on the scientific rhetoric to which we are daily exposed. This could easily lead us to believe that the real essence and solid foundation of our lives was from the beginning rigidly established inside those very first cells. There we find DNA macromolecules that, in a ceaseless flood of images, are presented to us as crystalline forms in the shape of a spiraling ladder — a ladder whose countless rungs constitute the fateful stairway of our lives. So, too, with the proteins and protein complexes of our bodies: we have been told for decades that they fold precisely into wondrously efficient *molecular machines* whose all-important functions are predestined by the DNA sequence.

The trouble is, biological researches of the last few decades have not merely hinted at an altogether different story; they have (albeit sometimes to deaf ears) been trumpeting it aloud as a theme with a thousand variations. Even the supposedly "solid" structures and molecular complexes in our cells — including the ones we have imagined as strict determinants of our lives — are caught up in functionally significant movement that the structures themselves can hardly have originated. (See Chapter 3, "What Brings Our Genome Alive?", and Chapter 4, "The Sensitive, Muscular Cell.")

Nowhere are we looking either at a static sculpture or at controlling molecules responsible for the sculpting. In an article in *Nature* following the completion of the Human Genome Project, Helen Pearson (2003) interviewed many geneticists in order to assemble the emerging picture of DNA. One research group, she reported, has shown that the molecule is made "to gyrate like a demonic dancer." Others point out how chromosomes "form fleeting liaisons with proteins, jiggle around impatiently and shoot out exploratory arms." Phrases such as "endless acrobatics," "subcellular waltz," and DNA that "twirls in time and space" are strewn through the article. "The word 'static' is disappearing from our vocabulary," remarks cell biologist and geneticist Tom Misteli, a Distinguished Investigator at the National Cancer Institute in Bethesda, Maryland.

Everywhere we look, shifting form and movement show themselves to be the "substance" of biological activity. The physiological narratives of our lives play out in gestural dramas that explain the origin and significance of structures rather than being explained by those structures.

Hannah Landecker, a professor of both genetics and sociology at UCLA, having looked at the impact of recent, highly sophisticated cellular imaging techniques on our understanding, has written: "The depicted cell seems a kind of endlessly dynamic molecular sea, where even those 'structures' elaborated by a century of biochemical analysis are constantly being broken down and resynthesized." And she adds: "It is not so much that the structures begin to move, but movements — for example in the assembly and

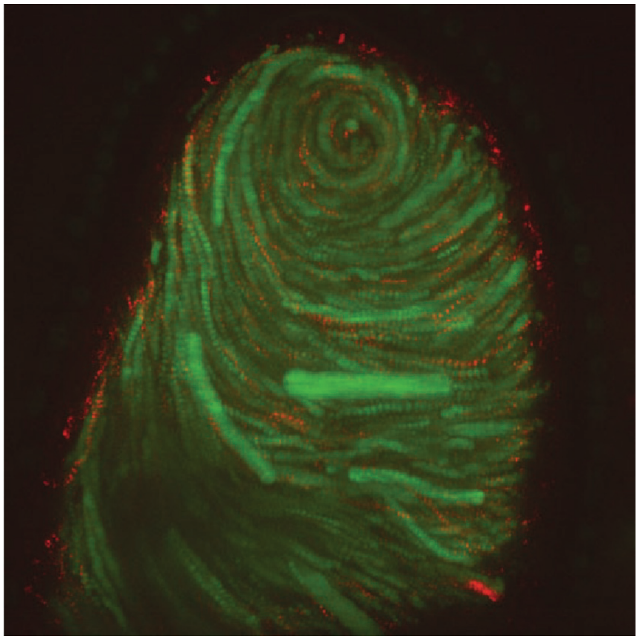

Figure 5.1. Multiple, superimposed images from a movie, showing movements in a fruit fly oocyte (a developing egg). Yolk granules are stained green, and tiny red fluorescent polystyrene beads have been injected into the egg to show the dynamism of flow in the egg body over time.[1]

self-organization of the cytoskeleton — begin to constitute structure" (Landecker 2012). See Figure 1, above.

And in a paper that appeared as I was writing this chapter, biochemists from Duke and Stanford Universities point out how inadequate is our knowledge of the action of biomolecules when all we have is a frozen structure of the sort commonly reported in the literature. "In reality," they say, "all macromolecules dynamically alternate between conformational states [that is, between three-dimensional folded shapes] to carry out their biological functions":

> Decades ago, it was realized that the structures of biomolecules are better described as "screaming and kicking," constantly undergoing motions on timescales spanning twelve orders of magnitude, from picoseconds [trillionths of a second] to seconds. (Ganser et al. 2019)

Why, after all, should we ever have expected our physiology to be less a matter of *gesturings* than is our life as a whole?

A Long Way from Crystalline Order

According to the old story of the machine-organism, a protein-coding DNA sequence, or gene, is not only mirrored in an exact messenger RNA (mRNA) sequence, but the mRNA in turn is translated into an exact amino acid sequence in the resulting protein, which finally folds into a fixed shape predestined by that sequence. It was a picture of perfect, lawful, lockstep necessity, leading from DNA through mRNA to a final, functional protein.

"There is a sense," wrote Richard Dawkins, "in which the three-dimensional coiled shape of a protein is determined by the one-dimensional sequence of code symbols in the DNA." Further, "the whole translation, from strictly sequential DNA read-only memory to precisely invariant three-dimensional protein shape, is a remarkable feat of digital information technology" (Dawkins 2006, p. 171).

And these proteins in turn were thought to carry out their functions by neatly engaging with each other in a machine-like manner, snapping into place like perfectly matched puzzle pieces or inserting into each other like keys in locks.

We now know, and already knew when Dawkins published those words, that everything about this narrative was wrong — and not only the parts about DNA and RNA. Among proteins (those "workhorses of the cell") every individual molecule lives in transformational movement — as a dynamic ensemble of rapidly "morphing," or interconverting, conformations — and therefore does not have a "precisely invariant three-dimensional shape."

But there is much more that wholly escaped Dawkins' computerized imagination.[2] Quite apart from the fact that each protein molecule rapidly shifts between distinctly different, folded structures, we now know that *intrinsically disordered proteins* — proteins that, in whole or in part, have no particular, inherent structure at all — are crucial for much of a cell's functioning. Researchers refer to "fluid-like" and "surface-molten" proteins (Grant et al. 2010; Zhou et al. 1999). This is why biophysicist Konstantin Turoverov and his Russian and American colleagues tell us that "the model of the organization of living matter is changing to one described by highly dynamic biological soft matter." For decades, they note, protein interactions were "considered to be rigid, where, for a given protein, a unique 3D structure defined a unique biological activity." However,

> it is now realized that many protein functions rely on *the lack of specific structure*. This recognition has changed the classical consideration of a functioning protein from a quasi-rigid entity with a unique 3D structure resembling an aperiodic crystal into a softened conformational ensemble representation, with intrinsic disorder affecting different parts of a protein to different degrees.[3] (Turoverov et al. 2019, emphasis added)

Clearly, the finally achieved protein need not be anything like the predetermined, inflexible mechanism with a single, well-defined structure imagined by Dawkins. Proteins can be true shape-shifters, responding and adapting to an ever-varying context — so much so that (as the noted experimental biologist, Stephen Rothman has written) the "same" proteins with the same amino acid sequences can, in different environments, "be viewed as totally different molecules" with distinct physical and chemical properties (2002, p. 265).

Many intrinsically unstructured proteins are involved in regulatory processes, and often serve as Proteus-like hub elements at the center of large protein interaction networks (Gsponer and Babu 2009). They also play a decisive role in molecular-level communication within and between cells, where their flexibility allows them to modulate or even reverse the typical significance of a signal,[4] in effect transforming *do this* into *do that* (Hilser 2013).

But the troubling question arises: if unstructured proteins, or unstructured regions in proteins, are not "pre-fitted" for particular interactions — if, in their "molten" state, they have boundless possibilities for interacting with other molecules and even for reversing their effects — how do these proteins "know" what to do at any one place and time? Or, as one pair of researchers put it, "How is the logic of molecular specificity encoded in the promiscuous interactions of intrinsically disordered proteins?" (Zhu and Brangwynne 2015). In the next section we will look at one of the most recent and dramatic developments in cellular physiology, which has seemed to many biologists to offer an approach to this problem.

But first we should note the continuing mechanistic bias in the negative descriptors, "disordered" and "unstructured," which I have grudgingly adopted from the conventional literature. Contrary to this usage, the loose, shifting structure of a protein need be no more disordered than the graceful, swirling currents of a river or the movements of a ballet dancer. Given the many living processes these proteins harmoniously support and participate in (including the movements of the ballet dancer), it would be strange to assume that their performance is anything *less* than graceful, artistic, purposive, and meaningful.

The Unexpected Phases of Life

It has become increasingly clear in recent years, that, quite apart from its cytoskeleton and membrane-bound organelles (Chapter 4), the fluid cytoplasm in each cell is elaborately and "invisibly" organized. Various macromolecular complexes and other molecules, in more or less defined mixes, congregate in specific locations and sustain a collective identity, despite being unbounded by any sort of membrane. Here we're looking at significant structure, or organization, without even a pretense of mechanically rigid form. How do cells manage that?

The problem was framed this way by Anthony Hyman from the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden, and Clifford Brangwynne from the Department of Chemical and Biological Engineering at Princeton University:

> Non-membrane-bound macromolecular assemblies found throughout the cytoplasm and nucleoplasm … consist of large numbers of interacting macromolecular complexes and act as reaction centers or storage compartments … We have little idea how these compartments are organized. What are the rules that ensure that defined sets of proteins cluster in the same place in the cytoplasm?

Even more puzzling, a "compartment" can maintain its functional (purposive) identity despite the rapid exchange of its contents with the surrounding cytoplasm. "Fast turnover rates of complexes in compartments can be found throughout the cell. How do these remain as coherent structures when their components completely turn over so quickly?" (Hyman and Brangwynne 2011).

Well-Structured Droplets

Part of the picture that has recently come into focus has to do with the phases of matter and the transitions between these phases. (Think, for example, of the solid, liquid, and gaseous phases of water, or of solutions and gels — matter in different states.) For example, it's possible for well-defined droplets of one kind of liquid to occur within a different liquid, like oil droplets in water.

We now know that molecular complexes containing both RNA and protein often gather together to form distinctive RNA-protein liquids that separate out as droplets within the larger cytoplasmic medium. Like liquids in general, these droplets tend toward a round shape, can coalesce or divide, can wet surfaces such as membranes, and can flow. The concentration of particular molecules may be much greater in the droplets than in the surrounding fluid, conferring specific and efficient functions upon the assemblies.

Enzymes and reactants can rapidly diffuse within the liquid droplet, while also moving with relative ease across the boundary between droplet and surrounding medium. Yet this boundary can remain distinct until phase-changing environmental conditions occur — conditions that might involve slight changes in temperature, pH, salt concentration, electrical charge, molecular densities, the addition of small chemical groups to proteins, degradation of proteins, the activity of gene transcription, or still other factors.

In this way, a very subtle change — originating, say, from an extracellular influence — can yield a dramatic transformation of cytoplasmic organization, just as a slight change in the temperature or salinity of water can shift an ice-forming condition to an ice-melting one, or vice versa.

Moreover, these phase-separated droplets can be highly organized internally: "multiple distinct liquid phases can coexist and give rise to richly structured droplet architectures determined by the relative liquid surface tensions" (Shin and Brangwynne 2017). Also, some parts may become gel-like,[5] and others may form more or less solid granules. Many such droplets may pass through stages, from more liquid to more solid, before dispersing. They form in response to particular needs, perform their work, and then pass away. Others are more or less permanent. Phase separation has been called "a fundamental mechanism for organizing intracellular space" (Shin and Brangwynne 2017) — one where "function derives not from the structures of individual proteins, but instead, from dynamic material properties of entire [protein aggregates] acting in unison through phase changes" (Halfmann 2016).

We also know now that weak, transient interactions among intrinsically unstructured proteins and RNAs can result in crucial, flexible "scaffolds" that help to assemble these phase-separated aggregates, drawing in a set of functionally related molecules. "Weak," "transient," and "flexible" in my description here might be taken as indicators of the living, responsive, and non-machine-like character of the activity.

When *things happen* in the cell, phase transitions often play decisive roles, as a University of Colorado group discovered when looking at phase transitions in a small roundworm. According to the researchers, these transitions "are controlled with surprising precision in early development, leading to starkly different supramolecular states" with altered organization and dynamics. "Reversible interactions among thousands of [these phase-separated] complexes," the authors found, account for "large-scale organization of gene expression pathways in the cytoplasm" (Hubstenberger et al. 2013).

How Do You Regulate Flow and Phases?

All this is, if you think about it, an amazing departure from the kind of picture once burned into the minds of biologists such as Richard Dawkins, from whom we heard some errant words above. Once there were dreams of compelling digital instructions in DNA; of machine-like interactions between molecules; of deterministic formation and functioning of proteins; of the cell as a collection of cleanly separate, well-defined structures; and of cellular processes with fully predictable outcomes. But this dream has faded in the clear light of an entirely different reality where, among many other things, we watch a subtle and almost incomprehensible play of material changes of state.

These state changes can be affected by infinitely varying factors, such as the momentary interaction between a few molecules of a particular sort, the "minor" modification of a molecule, the increasing concentration of molecules in a particular location, or the slight temperature change of a degree or two — the kind of change that, in the larger world of nature, can freeze the surface of a lake where, a few days previously, fish routinely breached the surface to feed on insects.

> Ice cools a drink, water carves a canyon, steam powers a locomotive … But ice brings down power lines, water floods towns, steam scalds skin. The context for these states matters, and there can be consequences if the appropriate state is perturbed or dysregulated. Now more than ever, we understand that physical states dictate biological function, and … recent papers have highlighted, at the subcellular and tissue levels, the importance of understanding those states and the conditions in which they occur. (Szewczak 2019)

We heard it asked earlier how intrinsically unstructured proteins "know" what to do at any one place and time. The old model assumed, rather puzzlingly, that random encounters between freely diffusing molecules accounted for many of the biological interactions we observe. But numerous researchers are now embracing the emerging picture of biological phase transitions as offering a very different understanding. Peter Tompa, a structural biologist from Vrije Universiteit Brussel in Belgium, sees certain phase transitions as directing "the movement of regulatory proteins in and out of organized subcellular domains" — part of the systematic maintenance of order in the cell[7] (Tompa 2013).

This is all well and good, but does it tell us (as is often implied) what "controls" and "directs" molecular engagements in relation to the distinct needs of the cell at different locations and times? If the organization of phase-separated aggregates is what coordinates the activity of proteins, then we shouldn't have to ask, as researchers are now asking, "Why do some proteins localize to only the nucleolus, while others can be found in both the nucleolus and Cajal bodies?" (Zhu and Brangwynne 2015). (Cajal bodies, like the nucleolus, are non-membrane-bound organelles found in the cell nucleus.) And, even if that question had a ready answer, the more fundamental issue would remain: if we assume that the well-timed and well-placed formation, structuring, and dissolution of phase-separated droplets leads to properly coordinated protein interactions, then

Figure 5.2. As an aside: Some researchers have applied the idea of biological phase transitions in a novel way. Certain species of penguins huddle tightly against the fierce cold of the sunless Antarctic winter (top photo), or aggregate in somewhat looser clumps when it is a little warmer (bottom photo), or move about more less independently when it is warmer still. So the different phases of their interaction are correlated with temperature, just as water varies from solid to liquid to gas, depending (among other things) on the temperature.[6]

what explains the intricately organized formation, structuring, and dissolution of the droplets?

This illustrates how (to get ahead of ourselves just a little bit) all attempts to answer questions of regulation in strictly physical terms never do really answer them. Rather, they lead only to an elucidation of previous physical states that again raise the same broad questions. There is no way to step outside the endlessly regressing physical explanations except by truly stepping outside them — except, that is, by turning to the play of intentions and end-directed activities that are implicit in the stories we find ourselves looking at.

After all, questions about biological regulation are questions about the *significant patterning* of living events, and these just *are* questions about a story — about the relation of continually adjusted means to the needs, strivings, and qualities of a particular life. It is no surprise, then, that our answers must be gained in the way we come to understand a story — not in the way we grasp the play of physical laws in, say, the movements of walking and speaking. (See Chapter 12, "Form and Cause in Biology," and Chapter 13, "Biological Explanations — Or Biological Portraits?")

And Then There Is Water — The Mediator of Flow

I have long thought that some day water will be seen as the single most fundamental, "information-rich" physical constituent of life, and that revelations in this regard will outweigh in significance even those concerning the structure of the double helix. Not many biologists today would countenance such a suggestion, and I am not going to mount a serious defense of it here, if only for lack of ability. Time will decide the matter soon enough. But I was particularly pleased to find that the widely read and respected *Nature* columnist, Philip Ball, once entitled a piece, "Water as a Biomolecule." In it he wrote:

> Water is not simply 'life's solvent', but rather an active matrix that engages and interacts with biomolecules in complex, subtle and essential ways … Water needs to be regarded as a protean, fuzzily delineated biomolecule in its own right. (Ball 2008a; see also Ball 2008b)

In another paper, Ball (2011) summarized some work bearing on the role of water in biological contexts. The main topic had to do with the relation between water, the binding cavity of an enzyme, and the substrate molecule to which the enzyme binds. It turns out, according to the authors of a study Ball cites, that "the shape of the water in the binding cavity may be as important as the shape of the cavity." Ball goes on to remark:

> Although all this makes for a far more complicated picture of biomolecular binding than the classic geometrical "lock and key" model, it is still predicated on a static or quasi-equilibrium picture. That, too, is incomplete.

Then he cites another paper on enzyme-substrate binding. There it is revealed that, before the binding is complete, water movement near the enzyme is retarded. "Crudely put, it is as if the water 'thickens' towards a more glassy form, which in turn calms the fluctuations of the substrate so that it can become locked securely in place. It is not yet clear what causes this solvent slowdown as a precursor to binding; indeed, the whole question of cause and effect is complicated by the close coupling of protein and water motion and will be tricky to disentangle. In any event, molecular recognition here is much more than a case of complementarity between receptor and substrate — it also crucially involves the solvent."

All this suggests to Ball that "changes in protein and solvent dynamics are not mere epiphenomena, but have a vital role in substrate binding and recognition."

Structural biologists Mark Gerstein and Michael Levitt (the latter a 2013 Nobel laureate in chemistry) wrote a 1998 article in *Scientific American* entitled "Simulating Water and the Molecules of Life." In it they mentioned how early efforts to develop a computer simulation of a DNA molecule failed; the molecule (in the simulation) almost immediately broke up. But when they included water molecules in the simulation, it proved successful. "Subsequent simulations of DNA in water have revealed that water molecules are able to interact with nearly every part of DNA's double helix, including the base pairs that constitute the genetic code" (Gerstein and Levitt 1998).

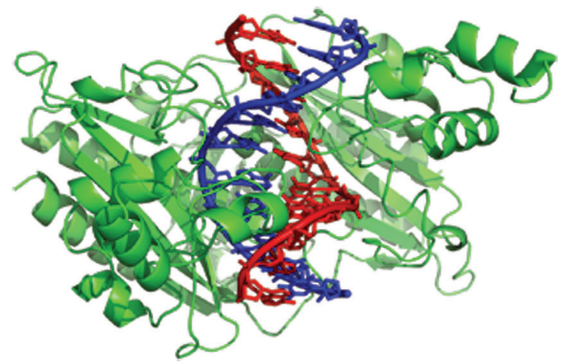

Figure 5.3. A typical "ribbon" diagram of a protein, representing certain basic structural elements.[8]

Early attempts to simulate protein molecules rather than DNA produced an analogous difficulty, with the same, water-dependent resolution. Gerstein and Levitt concluded their article with this remark:

> When scientists publish models of biological molecules in journals, they usually draw their models in bright colors and place them against a plain, black background. We now know that the background in which these molecules exist — water — is just as important as they are.

That was in 1998. More than twenty years later the background remains to be filled in, even if we are now seeing signs of change. Philip Ball (who likes to cite that Gerstein/Levitt remark, and who reproduces two images like figures 5.3 and 5.4), has recently noted "an interesting sociological question," namely, "why certain communities in science decide that particular aspects of a problem are worth devoting a great deal of attention to while others become minority concerns, if not in fact regarded as somewhat suspect and disreputable."

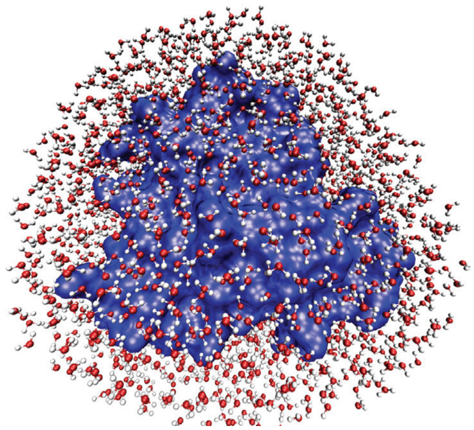

Figure 5.4. A representation of a protein's hydration shell, where the small, red-and-white figures stand for water molecules. Of course, both this and the preceding image represent almost nothing of the reality of the molecules (whatever we might take that reality to be), but only certain abstractly conceived features.[9]

He adds:

> Why should we place so much emphasis, for example, on determining crystal structures of proteins and relatively little on a deep understanding of the [water-related] forces … that hold that structure together and that enable it to change and flex so that the molecule can do its job? (Ball 2013)

Certain peculiar historical episodes have contributed to the disreputability of water as a "molecule of life." (Too many researchers have thought they glimpsed something about water that went beyond current principles of understanding, so that work of this sort came to be seen as mystically tainted or "on the fringe.") But surely part of the answer to Ball's question has to do with the longstanding distortion of biology due to the emphasis upon code and mechanism. It is much easier to imagine the step-by-step execution of a computer-like code or the clean insertion of a key into a lock than it is to come to terms with fluid transformations — that is, with what is actually life-like.

The high era of molecular biology that followed upon discovery of "the" structure of the double helix, was indeed the Age of Simplicity. We can be thankful that the feverish enchantment of code and crystal is now giving way to an increasing recognition of movement, flow, dynamically flexible interaction, and the continual transfiguration of form — prime narrative elements in the organism's story.

NOTES

1. Figure 5.1 credit: Copyright Margot Quinlan. Reproduced with permission.

2. In the chapter on "The Mystery of an Unexpected Coherence" we will look at *alternative splicing* of RNAs, one of many ways the DNA sequence is radically overridden by the larger purposes of the cell.

3. A terminological issue: Turoverov and colleagues speak more specifically of "highly dynamic biological soft matter positioned at the edge of chaos." The abstract and perhaps rather tiresome notion of "the edge of chaos" is better captured in this context by a picture of lifelike processes — powerfully organized, but in a dynamic manner that continually adapts to circumstances from a purposive, and therefore not *physically* predictable, center of agency. The predictability, such as it is, lies in the reasonable expectation of coherence in the interweaving meanings we observe. (See Chapter 2, "The Organism's Story," Chapter 9, "The Mystery of an Unexpected Coherence," and Chapter 10, "Biology's Missing Ideas.")

4. Biologists often speak of communication in terms of *signals* and *signaling*, where *signal* can hardly be distinguished in any absolute way from *cause*. However, "signals" tend to be spoken of where there are repeated, more or less stereotypical sequences ("pathways") of molecular interaction between different cells, leading to more or less consistent consequences. This happens, for example, when a gland secretes a hormone ("signal") that subsequently has effects in other parts of the body.

Wikipedia offered this definition of "cell signaling" in August, 2019: "Cell signaling is part of any communication process that governs basic activities of cells and coordinates multiple-cell actions. The ability of cells to perceive and correctly respond to their microenvironment is the basis of development, tissue repair, and immunity, as well as normal tissue homeostasis." This easy acknowledgment of "communication," "coordination," "governance," "perception," and "correct response" — all within a science that, on the surface, refuses the normal and unavoidably immaterial meaning of these terms — illustrates the Biologist's Blindsight described in Chapter 2, "The Organism's Story."

5. A sol-gel transition occurs when a solution (in which one substance is dissolved in another) passes into a gel state. The latter consists of a solid molecular lattice that is expanded throughout its volume by a fluid — water, in the case of a hydrogel. The fluid may constitute over 99% of the volume of the gel, yet the solid lattice prevents the gel from flowing like a liquid.

6. Figure 5.2 credit: Gerum, R. C., B. Fabry, C. Metzner et al. (2013). "The Origin of Traveling Waves in an Emperor Penguin Huddle," *New Journal of Physics* vol. 15

(Dec.). Available at https://iopscience.iop.org/article/10.1088/1367-2630/15/12/125022 under the Creative Commons Attribution 3.0 license.

7. Here is one of innumerable examples of the role of phase separation in physiological processes: “Cells under stress must adjust their physiology, metabolism, and architecture to adapt to the new conditions. Most importantly, they must down-regulate [reduce the level of] general gene expression, but at the same time induce synthesis of stress-protective factors, such as molecular chaperones … [We] propose that the solubility of important translation factors is specifically affected by changes in physical–chemical parameters such [as] temperature or pH and modulated by intrinsically disordered prion-like domains. These stress-triggered changes in protein solubility induce phase separation into condensates that regulate the activity of the translation factors and promote cellular fitness” (Franzmann and Alberti 2019).

8. Figure 5.3 credit: © Richard Wheeler (GNU FDL).

9. Figure 5.4 credit: From H. Frauenfelder et al. (2009). *PNAS* vol. 106, p. 5129.

REFERENCES

The references to this article are available online at http://natureinstitute.org/txt/st/bk/stream.htm.

Do Flowers Hear Bees?

continued from page 5

I’ve noticed in the literature a tendency to animalize plants as a means of giving them more credence as “substantial” beings on earth that we should be more aware of and care for. But this is not at all necessary. Plants are remarkable creatures in their own ways. We don’t need to analogize them with animals, which scientists do when they refer to “neurobiology” in plants.

But there is also a more deep-seated and ingrained habit of thought that anthropomorphizes plants and animals in the guise of mechanistic science. In the article about flowers and buzzing bees, the capacity of the flowers to create sweeter nectar in response to buzzing is considered to be a strategy: by increasing sweetness, the flower would be strengthening the likelihood that bees would return to the flower, which in turn would increase the likelihood of a bee pollinating the flower. What this way of thinking does is to assume flowers and bees are separate entities. Each is engaged in an ongoing struggle to increase the likelihood of its survival and reproduction. In other words, this way of viewing posits separateness as fundamental.

This view is a reflection of our human sense of separateness — that I am here and the world is out there, separate from me. But this felt separateness is also the starting point for us, as knowing beings, to discover how we are connected with the world and how the things of the world are connected. That is our task. It does not mean that in the world separateness is fundamental.

The more we study and learn, the more we find how things that we initially considered to be separate are in fact related. The plant’s existence is bound up with the sun, and in this sense the sun is not separate from the plant. Pollinators and plants are mutually dependent and they interweave. They are not in essence separate entities. And the research indicating that flowers may even have a relation to a sounding world, can help us realize that we have hardly begun to fathom how connectedness lies at the heart of life and the planet.

Cup plant (*Silphium perfoliatum*) with honey bee at The Nature Institute

REFERENCE

1. Viets, Marine et al. (2019). “Flowers Respond to Pollinator Sound Within Minutes by Increasing Nectar Sugar Concentration,” *Ecology Letters* vol. 22, pp. 1483-92. doi:10.1111/ele.13331

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