



Responding to Climate Change

The Earth as a Living Whole

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Climate change is now a presence to be reckoned with. Waldorf teachers in different schools and working with a variety of ages and subject disciplines are actively striving to respond. At the Nature Institute, we are answering this call with a series of colloquia for teachers in the natural sciences. During the first two of these gatherings, in summer of 2023 and winter of 2024, participants formed and worked with the shared picture that, as Jon McAlice writes in his report on the first colloquium, “climate change is not something that can be ‘fixed’, but rather challenges us to learn to know Earth differently.”¹ One aspect of this different form of knowing is an experienced understanding of the “Earth as a living whole.”² This work continues, with the next colloquium taking place in February, 2025, – after the time of this writing, but prior to its publication.

Learning to know Earth differently calls for not only new concepts, but also for a methodology appropriate for living beings. I refer here both to the human beings engaged in the teaching and learning but also to the more-than-human Earth, understood and studied as a living whole. This methodology must recognize both the profoundly relational existence of living beings – that is, existing in co-dependent relations with what is immediately observable and with what is hidden from view – and also the essential nature of beings as *processes* rather than as mere objects.

In this article, I first trace the conceptual development among contemporary biologists towards understanding living beings as profoundly relational, co-creative processes. I then describe concrete examples of practice, first as a researcher coming to understand the Scarlet Oak outside my window, and then as a teacher of high-school age students learning to understand combustion. In both cases, we work with direct observation, respectful experimentation, and a continual weaving together of our prior knowledge and lived experience with our work in the present moment. It is this methodology of working, more than arriving at one specific concept or another, that offers the possibility to understand the Earth as a living whole.

The concept of a “living whole” is not easy to define; what is a living being anyway? In their 1980 book, *Autopoiesis and Cognition: the Realization of the Living*, biologists Humberto Maturana and Francisco Varela coined the term *autopoiesis* to describe the self-sustaining quality of living beings.³ When my body is healthy, I am able to receive into myself substances external to me – the food I eat, the water I drink, the air I breathe – and transform them into my own bodily substance. My body is renewed through these processes in such a way that my own integrity is preserved: I am still myself even as cells in my body die away and are re-created out of fresh materials. This is the body’s self-sustaining quality.

As important as the self-maintenance of my own physical organism is my organisms’ relationship to the surrounding world. The concept of *sybiosis* reflects the mutual benefits that organisms gain through their interconnections. You may have learned in school that the nitrogen-fixing bacteria that infect the roots of legumes are there in a symbiotic relationship with the host plant. We may dig up a wild clover and note signs of infection on it: little white spots like pimples on skin. These spots signal the presence of bacteria that transform nitrogen from the air into a form that can be metabolized by the clover, and which in turn receive sugars and starches from the roots of the clover plant. In this description, we are presented first with a pathological description of the meeting of two organisms – an “infection” – and then with commodified exchange between clover and bacteria: they are separate but have come together in a mutually advantageous economic exchange. But this is a human social construct that we are imposing onto beings that are not buying and selling anything in their co-dependent existence; this concept of symbiosis is insufficient to describe how deeply life is interwoven in a manner that is neither pathological nor economic.

The feminist theorist Donna Haraway adopted the term *sympoiesis* to characterize not only interconnection through exchange, but indeed the profound *interpenetration* of living beings:

1 Jon McAlice, “Addressing Climate Change in Education,” *In Context* Fall 2023.

2 Ibid.

3 H.R. Maturana and F.J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht: D. Reidel, 1980).

Sympoiesis is a word proper to complex, dynamic, responsive, situated, historical systems. It is a word for worlding-with, in company. *Sympoiesis* enfolds autopoiesis and generatively unfurls and expands it. . . . Another word for these sympoietic entities is *holobionts*, or, etymologically, “entire beings” or “safe and sound beings.”⁴

Reading Haraway’s surging, vibrant, messy prose pulls one away from the tidy boundaries our rational consciousness imposes upon the continuity of existence. Even as we pull things apart, separating and analyzing in our efforts to understand the world, Haraway demands that we acknowledge what we have lost in the process. No being is ever separate from other beings but rather actively “worlding-with, in company.”

Coming from a different perspective, that of an evolutionary developmental biologist, Scott Gilbert also works with idea of the holobiont. In an article from 2024, he notes that at least half of the cells in our adult human bodies cannot be traced to the zygote formed in our mothers’ wombs: equally “me” are a host of micro-organisms essential for the healthy functioning of my body. Gilbert writes:

Organisms are now seen as holobionts, consortia of several species that interact metabolically such that they sustain and scaffold each other’s existence and propagation. *Sympoiesis*, the development of the symbiotic relationships that form holobionts, is critical for our understanding the origins and maintenance of biodiversity . . . these bacteria, fungi, protists, and archaea are not just travelling in our body and sharing our food. They are critical for our healthy physiology, development, and immunity.⁵

From self-sustaining, to mutually reliant, to “worlding-with,” we can trace an evolution of the concept of “living beings.” Indeed, one might ask, as Craig Holdrege does, “Where does a living being end?”⁶ When I pause to consider the natural environment, the built environment, the social fabric into which I am interwoven, it becomes increasing difficult to point to a boundary between one being and another. As Holdrege proposed in an opening lecture at the 2024 *Evolving Science* conference in Dornach,

I want to highlight more radically the nature of relational understanding. We can say: an oak tree grows out of an acorn; a plant grows out of its seed. That seems self-evident. It is correct, but it is also wrong. What’s missing is the other half. We also need to say: The environment becomes the oak through the acorn. If we can’t think those two together, we don’t have the living world, the etheric world.⁷

If we pause to think this thought concretely, we must form a picture of what actually takes place in the formation of an oak tree. Approaching the Scarlet Oak at the edge of the small meadow near my office, its many broad leaves, conveniently at eye level, call my attention. Right away, I notice that the top surface of the leaf is entirely different from the bottom surface. Particularly at the end of summer, the top surface of this scarlet oak leaf is very deep green and waxy: scratching my nail along its surface will cause the wax to come off in hard, transparent flakes. The underside of the leaf is entirely different. Much paler in color, it is tender in texture and without wax. On this underside the veins of the leaf are clearly evident in raised ridges, the largest of which is the central mid-rib, and then branching into side ribs that reach to the end of each lobe and into a network of finer and finer veins that trace a lacy network through the entire surface of the leaf. It is on the large veins that I can see, here and there, that galls have formed: little, hard, red growths shaped like berries with a flat cap. I learn that these are the co-creations of the tiny gall wasp and the oak tree; evidence that this tree is intimately connected with a world of insects that I have not perceived.

Meeting this tree in this way, situated in its own context, draws me into a relationship with this living being, just as the oak is in continual relationship with a multitude of living beings, of which the gall wasp is only one. At the same time, the gradual coloring of its leaves is only the most obvious sign that this scarlet oak is a continual process. This tree is no longer merely an object in my field of view, but it has begun to mean something to me; I want to know more about it. If we are to respond to climate change appropriately, we will need to have this same attitude towards the living Earth.

Now I have the right mood for respectful experimentation. Taking a leaf from the tree and into my laboratory, I can cut a cross-section and place it under the

4 Donna Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016).

5 Scott F. Gilbert, “Inter-Kingdom Communication and the Sympoietic Way of Life,” *Front. Cell Dev. Biol.* 12 (2024).

6 Cf. Craig Holdrege, “Where Does an Animal End? The American Bison,” in *Seeing the Animal Whole - And Why It Matters* (Great Barrington: Lindisfarne, 2021).

Also available as a Podcast, including a conversation with the author, through the website of The Nature Institute: natureinstitute.org

7 Craig Holdrege, “Sympoiesis: From Thinking About to Being With,” *Wochenschrift für Anthroposophie* 8 November 2024:12-14. Available on the Goetheanum website: dasgoetheanum.com.

microscope.⁸ Now I see the distinction between the top surface, the bottom surface, and the veins of the leaf further developed in the cell structures, which I can see under the microscope. The top layer of the leaf, the palisade mesoderm, shows tight, regularly arranged columns of cells. The bottom layer, the spongy mesoderm, shows irregular islands of cells, loosely arranged with air between them, and right on the edge of the leaf an opening, the stoma. In the middle, the veins reveal two different kinds of cell structures – the xylem and the phloem – through which substances are transported into and away from this leaf.

So now I consider what I know about the oak tree. Here, through this upper surface, light penetrates into the leaf. Through this bottom surface, via the stomata, air enters the leaf and circulates among the cells. Through the xylem, water and minerals are transported from the ground through the roots, trunk, branches, and twigs into the leaf. Here, in this leaf, air, and water unite through the agency of the light to form the very substance of the tree. Through the phloem, sugars and starches are carried away from the leaf into the other parts of the tree.

It is not simply that, through some process of accretion and elaboration, that which is contained within the acorn unfurls itself into an oak; I must also recognize how, through the acorn, the surrounding air, water, and light, are transformed into the oak tree. This is a powerful thought to inhabit, and now I work to extend that thought over the entire Earth, imagining the dynamic interplay of elements and forces that manifest as living beings.

Teaching and Learning

Surely, a true imagination of a living Earth, an imagination essential for a healthy response to our changing climate, must encompass these qualities of profoundly interconnected, dynamic processes that are living organisms. As educators, we can develop the necessary capacities for that imagination in our students.

For young children, it is direct experience that is the key. As McAlice describes, “Young children who are given the opportunity to experience the natural world directly through meaningful activities can grow to both

trust nature and to keep a sense of wonder alive for the beauty and mystery that we find in nature. Being with adults who care for Earth is essential.”⁹ He goes on to describe that as young people reach the next stage in their development, typically around 7th grade, a new approach becomes necessary. It is especially in the 7th-

10th grade span that careful study of observable processes – the practice of science – is essential for the development of just this picture of a living Earth.

As Waldorf teachers are well aware, an education in science that only presents facts to be memorized or models to be manipulated distances us from the world. When processes are reduced to only schematic marks on the page – think of the Lewis dot structures of your organic chemistry courses – the

world becomes a collection of dead objects that can be easily manipulated but lie impossibly distant from our lived experience. The view that scientific understanding must include attention to sense experience is by no means limited to Waldorf education. *The Blind Spot*, published in 2024 by MIT Press, begins with an eloquent description of the hazards of a mechanistic, reductionist science, including the bias towards what the authors term “smallism” – the mistaken belief that tiny things (the proton, the electron) are somehow “more real” than the original sense experiences from which these concepts were derived.¹⁰

When we bring students towards a meaningful encounter with observable processes, interacting with those processes through careful experimentation, and uniting their discoveries, through thinking, with other dimensions of experience, we set them on the path towards understanding the Earth as a living whole. Taking phenomena from the physical sciences – chemistry and physics – allows us to ethically engage with processes that are much more transparent than the complex and hidden processes of biological beings. We can identify physical and chemical processes that have this quality of dynamic transformation: studying them on a small scale, in the “scientific workshop,”¹¹ not only enables us to understand these important processes in their own right but also develops the skills and capacities we

9 Jon McAlice, “Addressing Climate Change in Education,” *In Context* Fall 2023.

10 Adam Frank, Marcelo Gleiser and Evan Thompson, *The Blind Spot: Why Science Cannot Ignore Human Experience* (Cambridge, MA: MIT Press, 2024).

11 This is the phrase used by *The Blind Spot* authors to describe the space of the laboratory experiment.

8 Much gratitude to Henrike Holdrege for teaching me how to do this.

need for coming to an authentic understanding of a living Earth. One recent experience I had teaching tenth graders will illustrate what this can look like.

Combustion

The motivation to look carefully at the process of combustion arose when, using a Bunsen burner to warm water, one group of students had its flame adjusted in such a way that the whole beaker was quickly covered in a thin, dry, black coating. What was it? We were able to wipe it off easily, so it did not seem to be a transformation of the glass, rather a deposit of some sort that had come from the flame. Indeed, the moment the golden yellow flame touched the glass of the beaker, this black substance appeared. One student suggested it was chalk – it had that dry, powdery feel, but we know that chalk is white. Another suggested it was soot – the same substance that blackens the inside walls of an open fireplace – and quickly others chimed in, remarking on its similarity to the charcoal sticks they use in the art studio and to the charred wood left over after a campfire. We remembered that soot is a form of carbon and recalled the many forms in which carbon appears, including as graphite in pencils and as diamond. But why had it appeared from that Bunsen burner and not from the others?

As a teacher, one does not always see it as possible to seize such moments as opportunities for inquiry. There is content to be covered, a lesson plan to follow: under other circumstances I would simply have told those students to adjust their flame properly – turning the little ring to admit more air – and moved on with what I had planned. Indeed, I had planned to take the course in an entirely different direction for the next six weeks. But there it was: the chance to look closely at something that had caught our interest, just as the Scarlet Oak outside my window had captured mine. We needed to study combustion.

Before the next lesson, I carefully prepared the classroom space, separating the desks so each one could be a little island of concentration, pushing the extra desks against the walls of the room, and lowering the shades on the windows.

The students entered in their typically friendly, boisterous way, chatting and joking with each other. They gathered around my table, each one getting a candle

and fixing it firmly in a holder. Then, each student sat down in his or her own space, and I turned off the room lights. I asked one particularly tall, fidgety, restless boy to take his candle to the lab room down the hall and light it, then to bring back the lit candle. The matches should stay in the lab, I directed.

As that single candle flame was carried into the darkened classroom, the entire room fell silent: quiet expectation filled the space. I directed one student to light her candle from the single flame that was brought into the room, and one by one each student took a turn to light theirs. Without admonition or instruction, these lively tenth graders had entered into a mood of reverence, and they spent the next twenty minutes in silence, simply writing down observations of the burning candle. We had established the right conditions for a meaningful encounter with combustion.

Studying the candle over the next several classes, we moved between engaged observation, experimentation, and bringing in what we knew about the candle from other sources. In another observation exercise, the students worked with watercolor paints, trying to match the colors that they saw in the different regions of the flame, including a particular golden yellow and an elusive blue. In the laboratory across the hall, they experimented with a metal spoon to investigate where exactly in the flame the soot was produced, with a bent piece of glass tubing to siphon off a heavy white vapor from a different part of the flame, and with a glass jar placed over the top of the flame to catch a clear, wet condensate. Each different substance was a delightful discovery. That white vapor could be caught in a tiny test tube, where it soon hardened into wax, while the clear, wet, condensate was something entirely different again – like your breath on the window, one student described, or the steam from your shower when it hits the cold mirror: water for sure.

What knowledge did we have of the paraffin that was fueling the flame? It is a hydrocarbon, and the class recalled what they had learned about hydrocarbons in their chemistry and earth science main lessons. Organic material, falling to the ground millions of years ago, covered by sand and rock until it was deep underground and subject to tremendous pressures of heat and temperature, transformed into what we call fossil fuels, then pumped out of the ground as crude oil and

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refined into the paraffin wax of our candles.

Gradually, all of these aspects of their work with the candle—observation, experimentation, and received knowledge—began to unite both in each individual student and in our collective work as a class. Each time we revisited our burning candles – over the gaps of days between classes – the recollection of these different aspects began to develop an imagination in the students of an amazing process of continuous transformation. Before our eyes, solid paraffin became a liquid in the cup at the top of the candlestick, a vaporous substance we couldn't see directly, but which we could catch if we interrupted the process, and then into invisible gasses: water on the one hand and carbon dioxide on the other.

In our own human bodies, a delicate form of analogous transformations take place; we can bring our awareness to the food that we eat, the oxygen-rich air that we inhale, and the water and carbon dioxide-rich air that we exhale, knowing that the internal processes of digestion and respiration are largely beyond our conscious awareness. As with the oak leaf, we are called upon to unite what we can see directly with what we can confidently infer and what we can only imagine to re-create a meaningful whole. So does our changing climate call us to reimagine Earth, in its visible and invisible aspects, as a living whole.

There is no end to these imaginations over space and time – thoughts of a closed loop or isolated cycle are inadequate to the task; we must also, for example, imagine the vegetation across the entire Earth taking up water and carbon dioxide and exhaling oxygen. There is nothing new in these ideas, but it is easy to reduce them to abstractions that can be manipulated as equations for combustion and photosynthesis, thus putting an end to our active engagement with our lived experience. Instead, concretely picturing all of these processes happening continuously across the globe, grounding them in our own experiences of the humble candle and a single oak leaf, can open up further generative questions about global processes.

Our February 2025 colloquium at the Nature Institute will include a close study of moisture. What is its relationship to temperature on the one hand and to pressure on the other? We will look closely at these processes both outdoors – frost forming on the edges of fallen leaves, melting to droplets and evaporating in the winter sun – and in the laboratory. The pressure differences resulting from evaporation and condensation are powerful forces, and essential ones for an

understanding of climate; studying together through observation and experimentation is always central to our methodology at the Institute. We will also imagine together what could serve as exemplary topics to take up in a tenth grade main lesson block on climate towards an authentic experience of the Earth as a living whole. I look forward to reporting on this further work.

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