Doing Goethean Science

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Practicing the Goethean approach to science involves heightened methodological awareness and sensitivity to the way we engage in the phenomenal world. We need to overcome our habit of viewing the world in terms of objects and leave behind the scientific propensity to explain via reification and reductive models. I describe science as a conversation with nature and how this perspective can inform a new scientific frame of mind. I then present the Goethean approach via a practical example (a study of a plant, skunk cabbage) and discuss some of the essential features of Goethean methodology and insight: the riddle; into the phenomenon; exact picture building; and seeing the whole.

Beginnings: Sensing Boundaries

I have vivid memories of Mr. Sinn's 9th grade science class. We did experiments with glassware, tubes, and Bunsen burners—that was neat. But then Mr. Sinn taught us how to explain the results of our experiments. He described processes—he must have been talking about molecules—that we didn't see. These became schemes with letters and numbers on the blackboard. We now were supposed to know what had really been going on. And I was lost. I didn't get it. What did the blackboard diagram have to do with what we'd been observing? This was an unsettling experience that had significant consequences: I avoided science like the plague in high school.

It is also my first memory of the kind of experience that I have had repeatedly since then and that has been key in my pursuing Goethe's approach to science. It is the experience of confronting what are called scientific explanations and feeling (in thought) a distinct sense of dissatisfaction. How can a phenomenon be explained by something that is supposed to underlie it and that is always less than the phenomenon itself? I have been amazed that what a large community of people feels to be an explanation leaves me with the question: what do I have now? What am I doing by leaving the phenomenon in order to explain it? Let me give a few examples.

In a college botany course I learned why plants that grow in shady places have broader and larger leaves than plants that grow in full sunlight. The reason given is that plants growing in shade don't receive as much light to do photosynthesis. Therefore they grow larger surfaces with which they can capture more light and produce more organic matter via photosynthesis. Plants have developed this strategy to survive and reproduce in

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shady habitats. This is a typical functional explanation that makes perfect sense—until you think the matter through a bit further. The larger the surface area a plant creates, the more substance it needs to build up and sustain its larger body. Wouldn't it be just as effective for the plant to stay very small with narrow leaves? In this way it wouldn't have to do so much photosynthesis since it could stay small. Both explanations make sense. I have yet to find a functional explanation of a phenomenon for which one couldn't find equally plausible alternatives. Such evolutionary explanations always fall short. They fall short because they are an attempt to get a grip on a complex biological phenomenon from only one narrow and limited perspective. I have shown this to be the case in celebrated textbook examples such as industrial melanism in the peppered moth and the long-necked giraffe (Holdrege 2003, 2004).

I can formulate the problem in another way. Every biology student learns that the fundamental question of biologists confronting a phenomenon is: what is the underlying mechanism? It may be a Darwinian survival strategy or a hormonal or genetic mechanism. In the search for such mechanisms two essential things happen. First, you isolate the phenomenon out of its context within the organism as a whole and, second, you seek to explain it in terms of a reduced set of quasi-mechanical processes. In the end what you come up with is a simplified picture of a phenomenon caused by an abstractly conceived underlying mechanism. (The neurologist Kurt Goldstein has elucidated this problematic side of science in his seminal work on holistic science, *The Organism* (Goldstein, 1939/1995).)

Take, for example, a "trait" that is explained by a "gene." (For an in depth discussion see Holdrege, 1996.) When Mendel discovered hereditary patterns in pea plants he focused his attention on particular characteristics such as seed shape or flower color. He mentally abstracted these characteristics from the plant. He could only do this with "clear and distinct" characteristics, that is, ones that don't vary much under changing conditions. He did not look at flower color as it changes from bud formation through flower maturation and wilting, nor did he worry about the slight variations in color that occur between different specimens of the same breeding line. Flower color grasped as a Mendelian trait entails bracketing out developmental changes and variation. The resultant trait is an isolated, distinct feature and it is quite straightforward to go from it to an underlying particulate factor—later called a gene—that is inherited and responsible for the appearance of the trait through the generations. The history of genetics shows the power of this way of viewing and working with organisms.

The problem is that both the trait and the gene are products of abstraction, so that one is explaining an abstraction with an even greater abstraction. The red flower color of a strain of pea plants is much more than a genetic trait, and the biochemical component of inheritance is much more than the genetic code. This is becoming increasingly clear even within the field of genetics, so that some geneticists question the value of the concept of the gene altogether. Geneticist William Gelbart writes:

> For biological research, the 20th century has arguably been the century of the gene. The central importance of the gene as a unity of inheritance and function has been crucial to our present understanding of many biological phenomena. Nonetheless, we may well have come to the point where the use of the term "gene" is of limited value and might in fact be a hindrance to our understanding of the genome. Although this may sound heretical, especially coming from a card-carrying geneticist, it reflects the fact that, unlike chromosomes, genes are not physical objects but are merely concepts that have acquired a great deal of historic baggage over the past decades. (Gelbart, 1998)

It's interesting how reality tends to catch up with science at some point.

I've sketched here a couple of experiences I've had with scientific concepts. Over the past 25 years I've become keenly aware of what these concepts do not tell us and do not reveal. And because they are often used as if they told us something beyond their own narrowly circumscribed domain, they often mislead and cover up phenomena. Becoming aware of such boundaries is significant, because—to paraphrase Hegel—in our gaining an awareness of a boundary we have already begun to transcend it. We are at the gateway to a new kind of understanding, to the further evolution of science that Goethe inaugurated.

Delicate Empiricism: Science as a Conversation

The realization that the phenomena we confront are always richer than the abstractions we use to explain them is central to a Goethean approach. This realization is the expression of a two-fold awareness or sensitivity that Goethe points to with his expression "delicate empiricism" (Goethe, 1829, in Miller, 1995, p. 307). First, we experience a phenomenon (a mouse, a wooded swamp, a range of blue hills in the distance, or the clouds moving across the sky) as a kind of fullness that calls forth wonder, curiosity, questioning. We want to get to know it better, or as Goethe states it radically, "become utterly identical with it" (ibid.). This is empiricism, because we orient all our striving around the phenomena themselves. A phenomenon is what meets the eye but we also experience it is as something more, as a kind of surface that is pregnant with a depth we may be able to plumb. But we realize that we will not fathom these depths with models and theories, which more likely than not will lead us away from the phenomenon itself. This brings us to the second mode of sensitivity: we are acutely aware of the thoughts we bring to the phenomenon, how we interact with the world through thinking. We know that in conceiving thoughts we can both illuminate and color our experience. The more we are aware of the thoughts we bring, the more transparent and illuminating they can be. We must become delicate in the way we work with our concepts in our efforts to let the depths of the phenomena disclose themselves.

Goethe describes the process of gaining knowledge in the following way:

> When in the exercise of his powers of observation man undertakes to confront the world of nature, he will at first experience a tremendous compulsion to bring what he finds there under his control. Before long, however, these objects will thrust themselves upon him with such force that he, in turn, must feel the obligation to acknowledge their power and pay homage to their effects. When this mutual interaction becomes evident he will make a discovery which, in a double sense, is limitless; among the objects he will find many different forms of existence and modes of change, a variety of relationships livingly interwoven; in himself, on the other hand, a potential for infinite growth through constant adaptation of his sensibilities and judgment to new ways of acquiring knowledge and responding with action. (Goethe, 1807; in Miller, 1995, p. 61)

In Goethe's view science entails "mutual interaction" with the phenomena. Engaging in this process we discover the "limitless" nature of connections and relationships in the world but at the same time our potential to continually grow and adapt ourselves to new, more adequate ways of knowing. Doing Goethean science means treading a path of conscious development. The question accompanying every aspect of the work is, "How can I make myself into a better, more transparent instrument of knowing?" In traditional science, we are much more likely to ask, "How can I find ways of adapting the phenomena to my specific approach so that I can answer my question?"

I have found the metaphor of conversation increasingly helpful in illuminating the nature of a Goethean approach to science. The metaphor brings to consciousness that doing science is a back-and-forth between partners in an ongoing process. It accentuates a kind of inner attitude that lies at the heart of doing Goethean science, one very different from the frame of mind one normally associates with science (although it informs, but often not explicitly, the work of many good scientists). Here, expressed in fairly general terms, are some of the elements of science-as-conversation. (See also Talbott, 2004.)

1) When I enter into a conversation with nature my interest has been sparked by some experience, my attention has been caught. I'm presented with a riddle and begin asking questions, observing, and pondering. In this way I give the conversation an initial focus. If the interaction between me and nature has no focus it can easily become chit-chat and not a conversation.

2) But if the focus I bring is too narrow and too rigid (for example, a narrowly defined hypothesis), we don't have a conversation, we have a drill (one-sided questioning). In any productive conversation the process itself is paramount. It's not just about me answering my pre-formulated questions, but centrally about what happens along the way. There will be surprises, moments of silence, tension. The back and forth between me and nature is dynamic and I attend to this process as an integral part of the conversation.

3) Taking the conversation-as-process seriously means realizing that it is open-ended. I don't know where we're going to arrive. With this awareness present at every moment, the conversation is imbued with an atmosphere of openness. I could also describe this attitude as a kind of animated looking forward to things unexpected that may arise.

4) Nature is my partner in the conversation. If I truly mean this and don't take the statement as a feel-good cliché, then I'm acknowledging that nature is something in its own right. I may not, at the outset, be able to say more than that. But the recognition of the other as something in its own right is a

pre-condition for any conversation. This recognition infuses respect into the conversation and gives it dignity. In saying this I don't mean that geologists will no longer crack open rocks with their hammers or botanists will stop pressing plants. However, knowing that I am involved in a conversation makes me more circumspect and I become more sensitive in what I think and do. I may ask, for example, whether I may be going too far and transgressing boundaries. I'm not talking here about abstract, prescriptive directives—since the conversation *is* a process, I can't know what will emerge out of it beforehand. But in any case, it is carried by an attitude of respect.

5) An essential feature of the conversation is that I listen to what nature has to say. Receptive attentiveness allows us to hear and see with fresh ears and eyes. It's the quality of open interest in what the other has to say. But it would not be a conversation if I only listened. I respond and interject. I am actively giving form to the conversation through my questions, observations and the new concepts I bring in. A vibrant conversation needs the movement between receptive attentiveness and active contributing.

6) In the course of any real conversation the partners change and evolve—they are in a different place than they were at the outset. It is easy to see that I as a scientist change in this conversation. I have gained new experiences, taken new qualities into myself and gotten to know the world more deeply. But what about nature? In a simple sense, any time we interact with nature through an experiment, we change nature. Field ecologists have recently discovered that even touching and marking plants in the field can affect their growth (Cahill, et al. 2001). Goethe's seminal essay "The Experiment as Mediator Between Object and Subject" (Goethe, 1792; in Miller, 1995, pp. 11-17) shows his keen awareness of science as a way of interacting with nature. Experiments don't "prove," they mediate a relationship. We are interwoven with nature and weaving new fabric when we do science.

There is another dimension to nature evolving in the conversation. Inasmuch as nature—the phenomenon I'm engaging with—has been recognized, worked with, and taken up into the human mind, it is appearing in a new form. Nature finds a new expression through the process of human knowing. This may seem to be a radical idea, but it is actually just a description of the process itself (see Steiner, 1894/1999). Unfortunately, most of us are held captive by the notion of the world "out there", separate from us "in here." The moment we wake up to the fact that we are part of the world and engaging in a conversation with her to get to know her (and ourselves) better, the captivity of a dualistic world view ends. We are freed to engage as participants *in* the world.

7) This realization helps us to see one more facet of science-as-conversation: I become aware that I am taking on a responsibility. I'm engaging in the world and whatever the outcome of the conversation, it will bear in part my stamp. I put to rest once and for all the comfortable specter of something called "value-free" science engaged in by some detached being called a scientist. Science is all about participation, and I can't distance myself from the process and its results.

So much for an introductory overview. The idea of science as a conversation grows out of the doing. But once you've become conscious of it, it becomes a kind of scientific conscience—an inner guide—for all further work: Am I aware enough of the process? Is a back-and-forth occurring? Am I listening or pushing an agenda? When your work becomes infused with a circumspect attitude of questioning wedded to a strong desire to engage in the phenomena, you can see what Goethe wanted to express with the phrase, "delicate empiricism." And you can also understand why he added that its practice belongs to a "highly evolved age," since it is dependent on transformation within the human being. Goethe's science involves the consciously evolving scientist.

In the following sections of this essay I will try to illuminate more fully the process of doing Goethean science by way of an example. I'll show how science-as-conversation can unfold and also discuss additional important features of a Goethean approach.

Engaging the Conversation

When I moved to the Northeast twelve years ago I met new habitats, plants and animals. Early in March I was down in a wooded swamp and saw some strange looking plants—maroon and yellow, fist-sized buds that emerged directly out of the icy ground. They had a beautifully curved and pointed form, something like the hats of elves you see in children's books. Nothing else in the wetland showed any sign of spring in this grey, frozen world. I was captivated—I began my journey to get to know the skunk cabbage.

So that's how it begins. Something captivates your interest, and you move towards it. For me this meant returning to the skunk cabbage again and again—in all seasons and at different times of the year. I did this over a period of six years, in which time I also read everything I could get my hands on regarding skunk cabbage (which wasn't a whole lot). What was my purpose? What was my goal? I know of no other answer than to say: I wanted to get to know the skunk cabbage. I felt it as a riddle that drew me towards it.

I didn't have a particular hypothesis that I wanted to test. I didn't want to "explain" the plant or its features in terms of competition or survival. Since I had been practicing the Goethean approach for many years, it wasn't very hard to avoid the trap and narrowing effect of wanting to explain. But when I'd go out with other people, I'd often be asked question such as: Why does it flower so early? Why does it heat up? Why do its leaves grow so large? I could tell them what some scientists thought and perhaps point out alternative explanations. But I'd also say, and that is more important, that before we can see whether it's even meaningful to ask such questions, we have to get to know the plant much more intimately. And just those "why" questions can hinder us from doing so.

So the conversation began. I began building up a picture of the plant's development through the year. To do this I made lots of detailed observations. The plant itself is a unity that transforms over time. I had a vague sense of that unity, but I had to get to know it by bringing together discrete observations. As Henry Bortoft puts it, "the way to the whole is into and through the parts" (Bortoft, 1996, p. 12). In every part you discover new phenomena and new questions arise. One danger here is that you let yourself get pulled into an endless process of analysis, where the whole and, successively, each part dies into further analysis. The only antidote I know to this problem—which is a major problem for all of science—is to periodically disengage from analysis, step back and ask yourself: How does this all relate to the skunk cabbage? I began my journey wanting to get to know the plant better. So I have to continually try to place all the knowledge I gain through engaging in the parts (analysis) back into the context of the plant as a whole (synthesis).

I tried to go down to the wetland to observe every week or two. I sketched the plants to help me look more carefully, and I also took photographs. Sometimes I would have specific questions: How are the flowers really shaped? Are the skunk cabbages that grow at the wetland edge any different from those that grow in the wetter core area? But at other times I would purposely go out without a content focus, with the attitude “let’s see what comes today.” I know some of my most interesting observations—such as discovering bees on their first outing of the season were visiting skunk cabbage flowers—came when I was walking with an “unframed mind.” As Thoreau writes,

> Be not preoccupied with looking. Go not to the object, let it come to you . . . What I need is not to look at all—but a true sauntering of the eye. (13 Sept. 1852, Journal 5: 343-44; in Dassow Walls, 1999)

Of course, we never engage in observing with a fully unframed or unfocused mind. We always have some kind of intentionality or attentiveness that orients us toward the world (or we fall asleep). But we *can* work on developing a kind of open, listening awareness—which is what Thoreau is pointing to with his expression “sauntering of the eye”—that is very different from going out with a specific question one wants to answer.

Through the weaving interplay of focused observation and open awareness you come to know the phenomena. It’s the most time-extensive part of doing science and most fruitful when you can move back and forth between the poles of focus and opening outward.

Exact Sensorial Imagination and Living Understanding

After I go out and observe, I make a point of actively re-membering the observations. With my mind’s eye I inwardly recreate the form of the leaves, I inwardly sense the colors and the smells, and so on. This process of conscious picture building is what Goethe called “exact sensorial imagination” (Goethe, 1824; in Miller, 1995, p. 46). It entails using the faculty of imagination to experience more vividly what I have observed. I try to be as precise as possible—and will often notice where I haven’t observed carefully enough, which I try to do the next time I’m out. When you do this kind of conscious picture building, you grow more and more connected to what you’re observing.

But there’s something else. The plant begins to reveal itself as a process. When we begin observing, we have many separate images, and we have to overcome separateness to begin seeing the plant as the living creature it is. The life of a plant plays itself out in the ongoing unfolding and decay of organs (leaves, stalks, flowers, etc.). We are presented with a drama of transformation that we can enter into. But we can't enter into it through observation alone. We need to utilize our faculty of imagination to connect within ourselves what *is* already connected within the plant. As Goethe writes:

> If I look at the created object, inquire into its creation, and follow this process back as far as I can, I will find a series of steps. Since these are not actually seen together before me, I must visualize them in my memory so that they form a certain ideal whole.
>
> At first I will tend to think in terms of steps, but nature leaves no gaps, and thus, in the end, I will have to see this progression of uninterrupted activity as a whole. I can do so by dissolving the particular without destroying the impression. (Goethe, 1795, in Miller 1995, p. 75)

So to begin to grasp the flow of life and its specific qualities in skunk cabbage, you have to work to make your thinking fluid (process-oriented) and dynamic. In Goethe's words, "If we want to approach a living perception (*Anschauung*) of nature, we must become as mobile and flexible as nature herself" (Goethe, 1807; translation by CH; in Miller p. 64).

I'd now like to give what you might call a report on my conversation with skunk cabbage. But it actually wants to be more than that. It's an attempt to give a portrayal, to paint a picture in words that will let you see something of the unique qualities of this plant. I hope to give you a glimpse of another being, although I'm all too aware of my inability to adequately express what I have met.

Skunk Cabbage—A Portrayal

To find the first spring plant in flower in our region—the edge of the Taconic range southeast of Albany, New York—you have to get out before it feels much like spring at all. It's March, the ground is still frozen, and frost comes nearly every night. Walking through the woods down a soft slope, you see the grey and brown tree trunks, a coloring mirrored in the ground litter of leaves from the previous year. There is no green. Not only the temperature but the whole mood of the woods is cool.

At the base of the slope there is wooded wetland—a flat expanse in which patches of ice spread around islands of bushes and small trees. In this still, quiescent world, little centers of emerging life are visible, the first sign of early spring—four-to-six-inch-high, hood-like leaves that enclose the flowers of skunk cabbage. (See figures 1 and 2; all drawings are by the author.)

Both color and shape are striking. Some leaves are deep wine-red or maroon, while in others this background coloring is mottled with dots or stripes of yellow or yellow green. The shape is hard to describe: it is like a spiral, sculpted hood drawn around itself, leaving only a narrow opening on one side. Not only the colors, but also the specific shapes are manifold; some are pointed and strongly twisted, others rounder and squat. As my eye sweeps over the twenty or thirty plants before me, my gaze is brought into a spiraling movement when it tries to rest upon any single specimen. The deep color is warm, the sculpted form alive.

Looking at skunk cabbage on one of the first warm, sunny March afternoons (it's maybe 50° F) with the light shining through the leafless trees and shrubs and illuminating the wetland floor, I often sense for the first time that spring is on its way. On such days I've even seen the first bees of the year flying in and out of the skunk cabbage hoods.

The hood is, in botanical terms, a highly modified leaf called a spathe. The spathe wraps around itself to form a space that encloses a spherical head of flowers, called a spadix (see figure 2). The spathe functions as a bud that holds and protects the flower head when it emerges out of the ground. But it is a bud that never unfolds. When the flowers are full in bloom, they are

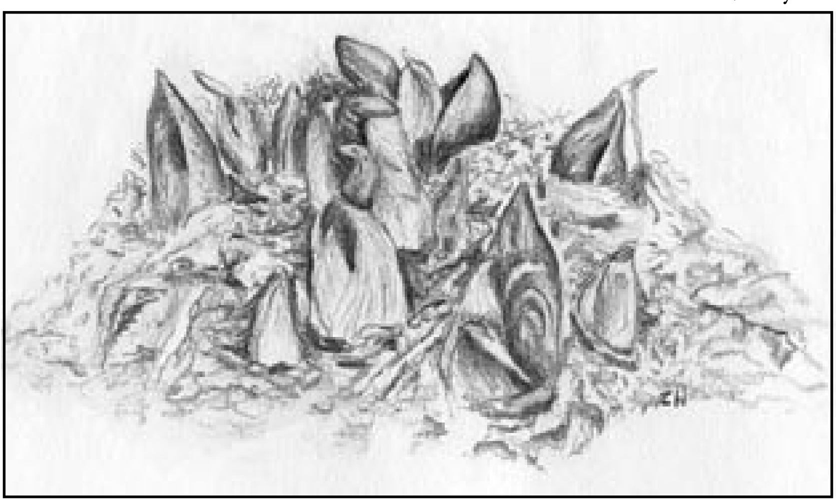

Figure 1. A group of skunk cabbage spathes and leaf buds in March.

Figure 2. Skunk cabbage spathes.

still enwrapped by the spathe. You can see the flower head only by peeking inside the narrow opening in the spathe.

The roundish flower head (about 2 cm in diameter) has a spongy consistency like the spathe itself. It consists of numerous small, tightly packed individual flowers (see figure 3). They have no petals, which make up the showy part of the flower in most plants. Rather, they have four inconspicuous, fleshy, straw-colored sepals (which in many plants form the bud leaves enclosing the petals) that never really unfold.

The flowers "bloom" when the stamens grow up between and above the sepals and release their pale yellow pollen. Following this the style grows out of the middle of each flower to be pollinated by insects carrying pollen from other flower heads. All of this happens *within* the enclosing spathe. These first flowers of spring never leave their protective enclosure.

A couple of times I've been lucky enough to see spathes growing up through a thin layer of ice, the ice melted around the spathe in a circular form. This is an indication of skunk cabbage's remarkable capacity to produce heat when flowering. If you catch the right time, you can put your finger into the cavity formed by the spathe and when you touch the flower head, your finger tip warms up noticeably. I have measured the temperature at the base of the flower head numerous times and have found it to be as warm as a 61° F when the surrounding air temperature was only 32° F. Biologist Roger Knutson found that skunk cabbage flowers produce warmth over a period of 12-14 days, remaining on average 20° C (36° F) *above* the outside air temperature, whether during the day or night. During this time they regulate their warmth, as a warm-blooded animal might!

Physiologically the warmth is created by the flower heads breaking down substances while using a good deal of oxygen. The rootstock and roots store large amounts of starch and are the likely source of nutrients for this break down. The more warmth produced, the more substances and oxygen consumed. Knutson found that the amount of oxygen consumed is similar to that of a small mammal of comparable size.

We must imagine that as the spathe grows out of the usually frozen ground, the flower head heats up and the warmth radiates outward. While in this heating phase, the flowers bloom, releasing pollen and being pollinated by insects. Not only can you see the first insects flying around between skunk cabbages, but you also find beetles and spiders crawling around within the warm enclosures of the spathes. You can even discover a spathe opening veiled with a spider net.

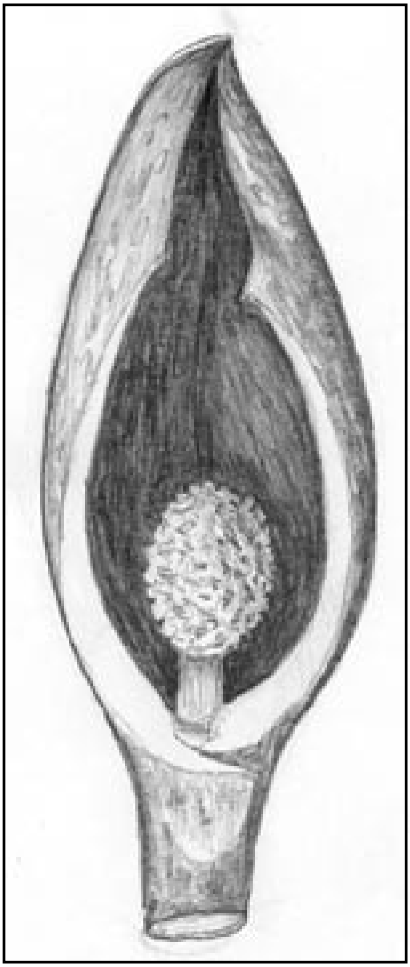

Figure 3. Shunk cabbage spathe; the front part has been cut off to show the flower head (spadix).

The flowers also release a noticeable odor at this time. On a calm day coming down to the wetland you can smell a lightly pungent, somewhat skunk-like odor. If you put your nose to the opening of a spathe or break off a small piece and crush it between your fingers, the scent is markedly stronger. Small flies and other insects are attracted to the flowers by the smell.

Due to the warmth production, a constant circulation of air in and out of the spathe occurs. From the flower head, warmth is generated and the air moves up and outward, while cooler air is drawn into the spathe. A vortex is formed with air streaming along the sculpted, curved surfaces of the spathe. In a habitat with numerous skunk cabbages, a microcosm of flowing warmth and odiferous air is created in which the first insects of spring fly.

This is the world of skunk cabbage over a number of weeks in March and sometimes into April: on the one hand, the enclosed, protected life just peering out of the still wintry earth and a flower that remains in a bud; on the other hand, the active, warmth-, movement-, and scent-emanating organism that creates a unique environment for the first stirrings of insect life. Skunk cabbage mirrors the quality of early spring—flowering at ground level in a bud that doesn't open, while at the same time helping to create the environment for its own development.

When the spathe emerges out of the ground, there is often the tip of a large bud next to it, sticking an inch or two out of the ground (see figure 4). This bud contains all the leaves that will develop on the plant and is often already visible in the previous fall, having developed in the summer and overwintered. Only when the spathe slowly begins to wilt does this tightly-packed bud of leaves begin to grow. It grows longer than the spathe and is shaped like the tip of a spear. Then, when the days begin to get noticeably warmer at the end of April and into May, the bud unfolds rapidly. It's clear that skunk cabbage now needs outer warmth to develop. The bright green leaves unfold in a beautiful spiraling pattern. Each leaf is rolled in upon itself and at the same time enwraps the next leaf. It's the closest thing to an archetypal process of unfolding you can imagine.

Gradually a large, funnel-shaped rosette of long-stalked leaves forms. The largest leaves reach three, occasionally four feet in length. By mid-May this surge of growth peaks and the wetland is flooded with green patches of skunk cabbage. The leaves are oblong in shape and have a long leaf stalk. The leaf stalks are thick, but also easy to crush. They have no woody fibers and consist primarily of air and water inlaid with soft plant matter. This consistency extends, untypically, into the flowering part of the plant: both spathe and flower are watery and spongy. By contrast, think of the distinct difference you find in a wild rose between the hard, prickly, wooded stems carrying divided, fibrous leaves on the one hand and the refined, almost rarified petals on the other.

A crushed leaf also exudes a skunk-like odor, and ingested leaf juice calls forth a strong inflammatory reaction in the mouth and esophagus of human beings. Skunk cabbage not only produces its own warmth, it also stimulates warmth processes. Few creatures eat the leaves. I've seen leaf buds and also spathes that have been nibbled upon. In one instance the wetland was covered with a late March snow and tracks of wild turkeys led up to the buds, which apparently they had eaten from. Early Swedish settlers in Pennsylvania gave skunk cabbage the name "bear-weed," since bears were known to feast on the buds and leaves.

In our area the leaves of the trees and bushes unfold in May and a homogenous dark green canopy has formed by mid-June. At this time the leaves of skunk cabbage begin to decay. They don't dry up and fall onto the ground to become part of the leaf litter that is slowly decomposed by fungi over the next year. Skunk cabbage has its own characteristic way of decaying. The leaves get small holes in them, begin to hang down and parts turn black and somewhat slimy. Eventually the leaves sink to the ground and dissolve. This dissolution occurs rapidly, so that already by the end of July or early August the leaves are gone. You only find a few remnants of the bases of the leaf stalks. What dominated the appearance of the wetland in May has disappeared in August.

As strange as this way of decomposing at first seems, after studying the plant more intensively you begin to see how it fits with other characteristics. While growing, a plant is in its most fluid state. It then forms hard fibers, which, in biochemical terms, is a process of condensation and drying out. When the plant dies even more water is lost, and decay of the woody fibers sets in. Skunk cabbage stays in the watery phase; its substances don't condense and dry out. Therefore the dying leaves appear to evaporate, since they are mostly water, and almost no dry matter is left on the ground to decay. Skunk cabbage unfolds rapidly and disappears rapidly.

The Whole in the Part

Through this sketch I want to give you at least a partial view into the life of skunk cabbage. (For a more a more complete portrayal, see Holdrege

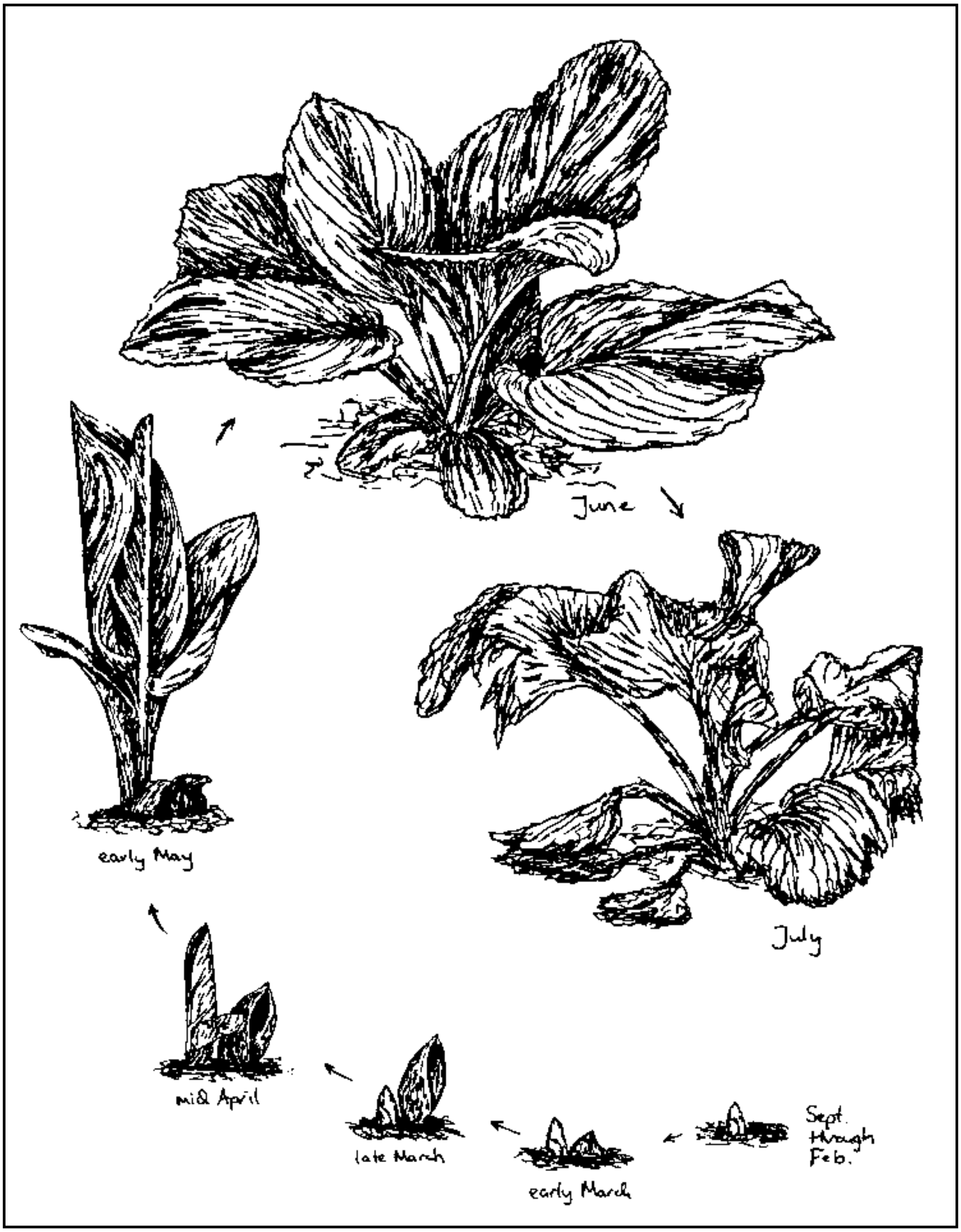

Figure 4. The development of skunk cabbage from early Spring to July, when its leaves begin to dissolve.

2000.) We can see its unique characteristics, but we can also see more. We can see how the various aspects of a plant's development, also in relation to its habitat, express certain unified tendencies.

When I see such relations, I sense that I'm finally beginning to actually meet and understand the plant, seeing through all the details to its unity and coherence. But at the same time, it's a new kind of territory. The terrain is difficult. Where before I had seemingly solid objects—the different parts of the plant in their shape, size, consistency, etc.—now I'm dealing with the qualities that are expressed *through* these parts. And qualities aren't things. It's a real struggle to express these qualities so that someone else can see what you're talking about.

Skunk cabbage expresses in many of its features a bud-like quality. Its flowers are housed in the large bud-like spathe, never extending out of this mantle. Skunk cabbage blooms in a bud at the time of year in which most flowers, later to unfold, are still tightly encased in their buds. Its flowers never reach the full light of day and the parts of a flower that normally unfold are highly reduced. While the petals are missing altogether, the small, fleshy sepals, all tightly packed into a sphere, open only enough to let the stamens and style slightly protrude. The flower head remains a big, fleshy bud within the bud-like spathe.

When the plant grows, leaf upon leaf unwraps out of the large bud. Since the stem of the plant never elongates but remains in the ground, the leaves never grow apart. Instead, they form a funnel-shaped rosette. The rosette is only fully open, that is, the leaves spread out in horizontal fashion, when the leaves are dying. Their life is in the unfolding bud; being unfolded signals decay. And skunk cabbage never stops laying down new buds, so that an established plant contains within it the spathe and leaf buds, not just for the next season, which is typical for perennials, but for a number of years to come.

We can go further and view these bud-like qualities in connection with skunk cabbage's dependency upon a wet environment. When I asked students in a field ecology course how they could determine where the wetland begins, they would often answer, "skunk cabbage shows you." Its roots need to be bathed in muddy soil throughout the year.

Skunk cabbage is not only dependent upon water, but also brings qualities of water—such as fluidity, movement, continuity, and the tendency to form surfaces—to expression. Early in spring, when stasis reigns in the wetland, skunk cabbage brings movement and life. The spathe grows out of the frozen ground and expresses in its form the congealed movement of spiraling surfaces. With the help of water, solid starch transforms into fluid sugar sap. Rising from the roots and rootstock, the fluid sugar is utilized in all growth processes. Moreover, large amounts of sugar are broken down to produce the warmth in the flower head. This transformation from solid starch to flowing sugar sap to radiating warmth is mediated by water and brings movement into the dormant landscape of early spring.

The radiating warmth in turn brings the air and insects into motion. When the leaves grow, you can almost see the water moving out of wet soil through the roots into the leaves, swelling and unfolding them. The leaves have a large, undulating surface that is like a conduit for water. They don't have a thick, waxy cuticle that prevents transpiration. As a result, water is continually flowing out of the soil, into and through the plant, and into the air, increasing the humidity of the lower layer of air in the wetland.

When skunk cabbage leaves decompose, they don't dry up and crumble; they dissolve. With few fibers, they consist mainly of water and air, as do the spathe and flowers, and disintegrate into these elements. Skunk cabbage embodies wateriness, growing and decaying in its watery world.

The Unity of the Organism

As the process of knowing unfolds—the conversation with the plant—you begin to see the unity of the plant. The remarkable thing is that when you build exact pictures over and over, moving from one characteristic to the next, patterns emerge. You begin to recognize how the characteristics express a whole—the unity begins to reveal itself. When you go back to characteristics you have studied before, they may suddenly express the unity you have discovered through another part. You have an "aha" experience in which you recognize connections between what previously appeared to be separate facts. You see a common watery, bud-like quality in the form and consistency of spathe, flower head and leaves. Skunk cabbage reveals the fluid quality of water in the way it unfolds and decays, as well as in its undulating, flowing forms. And in all of these characteristics you can see a vivid picture of early spring—a plant that is bud-like in so many ways and yet unfolds to bring the first life and movement to a still slumbering habitat.

While you have to work hard to get to such insights, you cannot force them. If you try to, you can be pretty sure they won't come. This is a stage of knowing where you have to learn patience. You prepare the ground, but the moment of seeing always involves an act of grace. Or maybe we could just say: we have to wait till the world speaks. As Goethe describes:

> I persist until I have discovered a pregnant point from which much may be derived, or rather—since I am careful in my work and observations—one which yields several things, offering them up of its own accord. If some phenomenon appears in my research, and I can find no source for it, I let it stand as a problem. This approach has proven quite advantageous over the years. When I found I could not solve the riddle of the origin and context of some problem, I had to let it lie for a long time; but at some moment, years later, enlightenment came in the most wonderful way. (Goethe, 1823, in Miller, 1995, p. 41; translation modified by CH)

Once you've come to understand a plant in this way, you never encounter it with the remark, "oh, that's just a skunk cabbage." Rather, you meet it with expectation and interest, wondering what else it has to show you. And this attitude begins to inform your overall orientation toward nature. Any other plant, beetle, or bird you see appears immediately as a riddle and not a thing. You know that each carries within itself—as you've experienced in skunk cabbage—a whole, unique world that's just waiting to be disclosed.

Doing Goethean Science

One of the problems with talking *about* doing Goethean science is that the essence is in the doing itself. That's why I have given what might seem to be undue attention to a concrete example. I'll conclude this essay by pulling back from the example and presenting some of the key features of a Goethean approach as I've described it.

Preparing the ground—A new attitude of mind

All science has its roots in human questioning and the search for understanding. As far as I can see, most people who are drawn to Goethe's approach to science recognize in it a way of understanding nature that can take them beyond the boundaries of what has developed as mainstream science. At the heart of the Goethean approach is the realization that as a scientist I must develop new capacities in order to do nature justice in my work. It's not just a matter of developing new instruments or refining the intellect, but developing new ways of knowing that can illuminate to the phenomena in ways that science has largely neglected (or even deemed unscientific).

Out of this awareness arises the striving to develop a gentle sensibility that does not violate the phenomena in the process of getting to know them. It's an active conversation, but one in which I hope the other—as something in its own right—can reveal itself. As Goethe writes, the scientist strives to "find the measure for what he learns, the data for judgment, not in himself but in the sphere of what he observes" (Goethe, 1792, in Miller, 1995, p. 11). This is the attitude that Goethe suggests with his expression "delicate empiricism" and that I've described above through the metaphor of conversation. As a kind of underlying intentionality it permeates all the work one does and grows as a capacity the more one works.

For this attitude of mind to actually inform every fiber of one's work means removing many obstacles—habits of the mind that have us search for single causes, for general theories, for reductive explanations. In the end it means, in the words of Owen Barfield, ridding oneself of all "residues of unresolved positivism" (in Sugarman, 1976, pp. 13-15). This is not an easy task, and one that never ends. Yet the striving (and some success!) is absolutely necessary if the world is to show herself from new sides. In his description of phenomenology as a new way of viewing, Edmund Husserl is speaking out of the soul of the Goethean scientist:

> That we should set aside all previous habits of thought, see through and break down the mental barriers which these habits have set along the horizons of our thinking, and in full intellectual freedom proceed to lay hold on those genuine philosophical problems still awaiting completely fresh formulation which the liberated horizons on all sides disclose to us—these are hard demands. Yet nothing less is required. What makes the appropriation of the essential nature of phenomenology, the understanding of the peculiar meaning of its form of inquiry, and its relation to all other sciences so extraordinarily difficult, is that in addition to all other adjustments a new way of looking at things is necessary, one that contrasts at every point with the natural attitude of experience and thought. To move freely along this new way without ever reverting to the old viewpoints, to learn to see what stands before our eyes, to distinguish, to describe, calls, moreover, for exacting and laborious studies. (Husserl, 1913/1962, p. 39)

Practicing Goethean science

The Riddle. This is the beginning of any investigation. I am drawn to a particular phenomenon and want to get to know it better. I've met something in the world that is a riddle I want to attend to. And because each person has a different biography—carries a unique world within herself—and is drawn to different features of the world, there is an endless and beautiful array of possible questions and areas of focus. I have colleagues who are physicists, chemists, ecologists, botanists, and zoologists. They are not only investigating different realms of phenomena, but take somewhat different approaches based on who each of them is. This does not make the work "subjective," but merely points to the fact that in any scientific endeavor the subject as a particular being is actively at work. And the riddle that draws a particular person is the beginning of a pathway into the world that is specific, but can be shared with others. (We live, after all, in one world.)

Into the Phenomena. This is exploration, getting to know the phenomena. As Goethe wrote in connection with his work in optics:

> The greatest accomplishments come from those who never tire in exploring and working out every possible aspect and modification of every bit of empirical evidence, every experience. (Goethe, 1792; in Miller, 1995, p. 15)

You really have to get to know the phenomena you're dealing with from as many sides as possible. If you're doing experiments, then it's a matter of varying them in a methodical way to build up a rich picture. It's not about proving (or falsifying) a particular hypothesis (Ribe and Steinle, 2002). In studying a living organism, you want to gain a many-sided picture of the life of the organism and its relation to its environment. In this work you make your own observations, but you also interact with and utilize the work of others (which may entail doing a good amount of separating out of theory and interpretation). Here is where a research community evolves. As Goethe writes,

> What applies in so many other human enterprises is also true here [in science]: the interest of many focused on a simple point can produce excellent results…. I have always found working together with others so advantageous that I have every reason to continue doing so. (Goethe, 1792, in Miller pp. 12-13; transl. modified by CH)

Since the phenomena are endless, this work is also without end. I can never get "all the facts," but my goal is also not an encyclopedic totality of information. It's more that I never cease to be interested in what the phenomena—perhaps some unassuming, seemingly esoteric detail—may reveal to me about the world. In my own work I often find that we don't know nearly enough about the animal or plant I'm studying. I do extensive literature searches and speak with experts, am enriched by all I find, but am usually left feeling I'd love to know much more. I also discover how theory-burdened so much of science is, with a small number of facts being marshaled to apparently support grand ideas.

Exact picture building. While getting to know the phenomena, I intensify my experience through exact picture building—Goethe's exact sensorial imagination. At first this may be a completely separate activity from being out and observing. I retreat from observation and quietly build up a precise inner picture of what I've experienced. The more I've done this, the more I find that my observing and perceiving becomes dynamic and full of life. I become active while perceiving, following inwardly the shapes, colors, smells, or tones as I observe. I sculpt the shapes while looking. This is where you notice how the picture-building as an exercise becomes integrated into your concrete interaction with the phenomena. You begin to see more intensely.

This work helps me to enter more deeply into the phenomenal world. It also gives my experience of the organism more continuity. The connectedness of all the details within the organism itself also becomes a connectedness within me.

I have come to see this activity of exact sensorial imagination to be the counter pole to theory building in traditional science. In both cases one is inwardly very active. But in exact sensorial imagination, the work of picturing—building images and letting the one transform into the other—keeps us close to the phenomena. We close the gaps that are given through our discrete observations and in this sense go beyond what perception gives us, but our whole intention is to take in the world. In theory building, I construct a picture or concept out of myself which fits the phenomena to a greater or lesser degree. Often, because we can know our own thoughts in such a transparent way, we become more interested in the theory than in the things the theory is supposed to explain. The tendency to reify concepts—which Whitehead called the fallacy of misplaced concreteness—is widespread in contemporary science (Whitehead, 1925/1967; especially chapters three and four). Theories tend to take on a life of their own and we may begin to see only the theory in the things. In this way a theory can become, in Goethe's words, "lethal generality." Concrete picture building has the cathartic effect of re-orienting our attention to the phenomena, while dissolving hard-and-fast ideas through mental molding and remolding.

Seeing the Whole. This is the "step" that we've been preparing for in all the other work. Or, stated more accurately, this is what can reveal itself in the course of one's striving to get to know the phenomena. As I said above, it is an experience of seeing unifying relations, which may or may not happen during any investigation. When it occurs, it fills you with the greatest joy and you realize: "now I am knowing." We can use the word intuition here as long as we don't think of something vague, but rather a nondiscursive form of seeing connections that is comparable to the experience one can have most purely in mathematical insight.

In the example of skunk cabbage I showed how you can see a bud-like, watery quality in various characteristics of the plant. Its wholeness speaks through its parts and its relation to the environment. If you imagine this mode of cognition applied on a larger scale, you come to what Goethe writes about as the "archetypal phenomena" in his color work, or the "type" (*Typus*) and the archetypal animal or plant (*Urpflanze; Urtier*) in his biological studies. (He also speaks of "entelechy," or "idea.") What term one uses is much less important than the quality of knowing itself. Here's how he describes the whole process, brilliantly condensed into a few sentences, that leads to a seeing that goes beyond, but is fully rooted in, empirical observation:

> If I look at the created object, inquire into its creation, and follow this process back as far as I can, I will find a series of steps. Since these are not actually seen together before me, I must visualize them in my memory so that they form a certain ideal whole.
>
> At first I will tend to think in terms of steps, but nature leaves no gaps, and thus, in the end, I will have to see this progression of uninterrupted activity as a whole. I can do so by dissolving the particular without destroying the impression….
>
> If we imagine the outcome of these attempts, we will see that empirical observation finally ceases, inner beholding of what develops begins, and, at last, the idea can be brought to expression. (Goethe, 1795; in Miller, 1995, p. 75; translation modified by CH)

If you don't pay attention to the process and context out of which Goethe speaks about bringing an idea to expression, you could imagine "idea" to be something abstract or bloodless ("just another theory"). But it's not. It has much more the nature of seeing a being. That's why Goethe was so distraught when Schiller reacted to his description of the archetypal plant by stating, "that is not an observation from experience. It is an idea. " Goethe responded: "Then I may rejoice that I have ideas without knowing it, and can even see them with my own eyes"(Goethe, 1817; in Miller, 1995, pp. 18-21).

So when Goethe says there is "delicate empiricism which makes itself utterly identical with the object, thereby becoming true theory" (Goethe, 1829, in Miller, 1995, p. 307), then "theory" is to be understood in the sense of the ancient Greeks as a "seeing of the mind" or "beholding" and not as the abstract "theory" as we know it from modern science. If we use the term "idea" then we must think of an idea that Goethe could, in the end, see sensibly/supersensibly in every plant. Reflecting on his botanical studies, Goethe writes near the end of his life,

> A challenge…hovered in my mind at that time [1787] in the sensuous form of a supersensuous plant archetype [*Urpflanze*]. I traced the variations of all the forms as I came upon them. In Sicily, the final goal of my [Italian] journey, the conception of the original identity of all plant parts had become completely clear to me; and everywhere I attempted to pursue this identity and to catch sight of it again.…. Only a person who has himself experienced the impact of a fertile idea…will understand what passionate activity is stirred in our minds, what enthusiasm we feel, when we glimpse in advance and in its totality something which is later to emerge in greater and greater detail in the manner suggested by its early development. Thus the reader must surely agree that, having been captured and driven by such an idea, I was bound to be occupied with it, if not exclusively, nevertheless during the rest of my life. (Goethe, 1831; in Mueller, 1989, p. 162).

So finding the fertile idea is at once a completion of a process and the beginning of a new one. As an end, it brings us full circle to a more conscious glimpse of the being—the riddle—that formed the starting point of the investigation. As a beginning, it is the soil for further work and vital new insights. Goethe's approach to science is itself a fertile idea that still has ample life to unfold.

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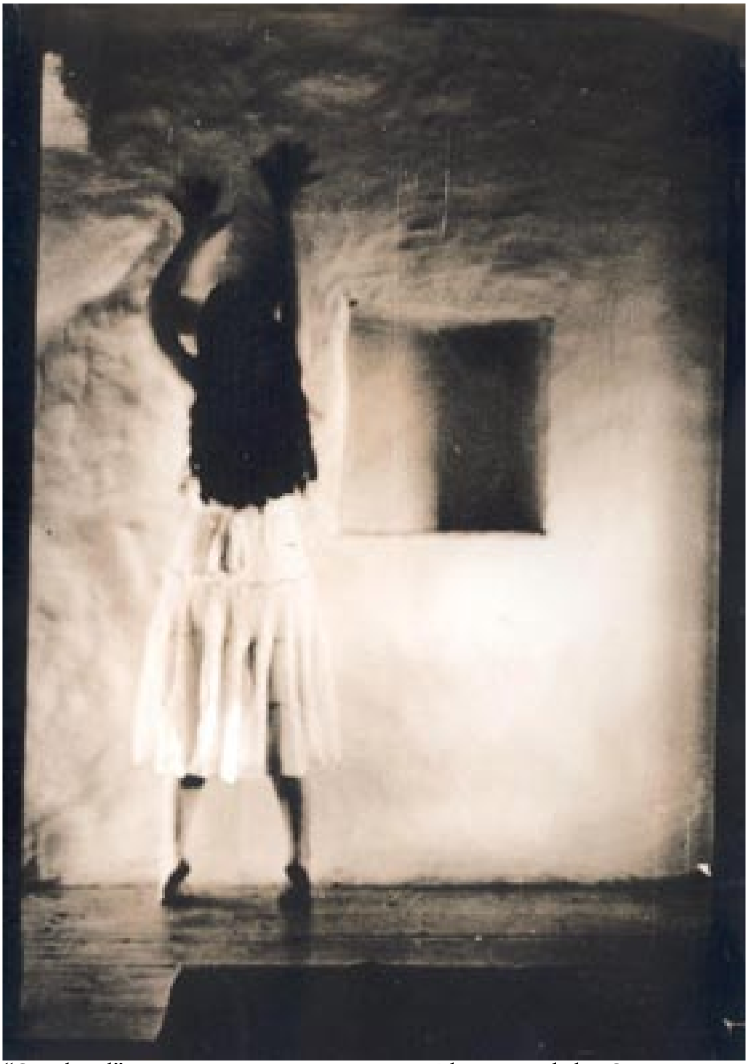

“Scotland” Photograph by Syrie Kovitz