Chapter 7
Ethical-Ecological Holism in Science Pedagogy: In Honor of Sea Urchins

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Using model animals in research "forms the core of biological knowledge" (Hedges 2002, p. 838) and this use has dramatically improved our understanding of and treatments for conditions such as heart disease, diabetes, and epilepsy. While we acknowledge the benefits to science and humankind, we also believe that animal usage for education must be considered carefully in the context of ethics. Such consideration, we argue, would be apropos to humans' self-identity that they have self-awareness as morally responsible beings. But this needed self-awareness undergirding moral responsibility is often misconstrued as sentimentality based on anthropocentricism. Herzog (2005) comments: "[s]cientists often assume that objections to the use of animals in science are based on sentiment and misplaced anthropomorphism"; however, "… the philosophical arguments both for and against the use of animals by humans are sophisticated and complex" (p. 15). We (the three authors of this chapter) are interested in developing a philosophical argument that offers an alternative paradigm for a scientific methodology that fully acknowledges the Other and takes humans' moral responsibility towards all earthly beings and our mutual flourishing. One such alternative that we would like to introduce in this chapter is a Goethean vision of science and scientific method wherein "[w]e develop the capacity to become *ethically responsive* to our obligations to the observed" (Robbins 2005, p. 123). This ethical responsiveness, it turns out, coincides with

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aesthetic considerations and sensibility in Goethean science. The philosophical theme of "ethics and aesthetic are one" (Bai 1997, p. 37) is pertinent here and will be explored in this chapter. Goethean science, as we will see, emerged during the so-called Romantic period in European history. Romanticism in science reminds us of the important "interrelationship of philosophy and science for science education" (Hadzigeorgiou and Shulz 2014, p. 1999).

This chapter develops the groundwork of holistic science pedagogy through exploring the Goethean scientific paradigm. We will share stories and poems of our reluctant participation or outright refusal in science labs involving animal experimentation. Through these embodied inquiries, we propose a philosophical rationale for moving away from anthropocentricism and an implied hierarchical worth of beings. We contend that students' experiences with dissection, often vivisection, presumes and reinforces the idea that other-than-human animals have a lower moral status, if any status at all. Our collaborative work in this chapter calls for a shift to an ethical-ecological framework for science pedagogy by animating the world and imbuing it with sacredness through aesthetic and contemplative practices alongside Goethean scientific investigation.

We begin our foray into the new vision of science pedagogy with a brief look at the sea urchin, a model organism in North American biology labs. This look is then followed by narratives of our respective experiences of lab work.

7.1 The Sea Urchin: A Model Organism

Model organisms are used in science to research anatomical, behavioral, genetic, and other biological information about the human species (Hedges 2002). Most of these organisms are easy to care for, abundant, and have physiological functions similar to those of *Homo sapiens*, giving the construed data a certain comparative value. Despite the many limitations of using nonhuman animals to better understand human biology, the use of lower model organisms is not predicted to decline for at least another 20 years (Hunter 2008).

Sea urchins are model organisms for teaching and researching many biological concepts, including embryology (Vacquier 2011), genetics (Cameron et al. 2006), molecular biology (Killian et al. 2009), and evolutionary biology (Koga et al. 2014). Aristotle observed sea urchin anatomy and described these organisms in his *Historia Animalium*, circa 343 BCE. The urchin's mouth is named Aristotle's lantern, inspired by his writings and attributed by early zoologists to refer to the jaw structure. However, recent excavations in Greece (Voultsiadou and Chariton 2008) suggest that Aristotle originally intended his lamp metaphor to refer to the urchin's test, or outer calcite shell. In the late 1870s, H. Fol and O. Hertwig investigated sea urchin fertilization, and in 2006, the purple sea

urchin's genome—more than 23,000 genes—was sequenced by a team of over 200 scientists (Cameron et al. 2006).

The sea urchin belongs to the class Echinoidea, a group of marine invertebrates with just over 1,000 known extant members (Kroh and Mooi 2011). At the phylum level, sea urchins (Echinodermata) are closer to humans (Chordata) than any other phyla. Compared to all the genome-sequenced nonchordate animals to date, sea urchins bear the closest genetic relation to humans (Cameron et al. 2006). Despite their stark dissimilarities from *Homo sapiens*, such as radial symmetry, presence of tube feet, and lack of eyes and other mammalian sense organs, both sea urchins and humans possess complete digestive tracts, internal skeletons, and bilaterally symmetrical embryos (McClay 2011). This latter point is of importance to biology labs, because the early embryonic stages—from fertilized egg, to cleavage, morula, blastula and gastrula—bear significant likeness for humans and urchins.

A common biology experiment used to teach embryology involves students extracting sea urchin gametes, fertilizing the released eggs with sperm, and observing the results under a microscope. For this laboratory procedure "adults may require an electric shock of 6–10V to induce spawning" (Vacquier 2011, p. 554). Another option is to inject urchins with a potassium chloride solution to stimulate gamete release. In such teaching materials, there is no mention of sea urchin distress or limiting sea urchin mortality. Rather, the implicit assumption seems to be that the suffering of sea urchins (which possess a primitive nervous system compared to humans) is not only justified, but also not even worthy of ethical consideration—so far removed, in fact, to be omitted entirely from academic discourse. Science as epistemology assumes, as a matter of course, that this animal is merely an object, and its internal organs are mechanisms to be poked, prodded and studied without an ethical regard.

For studying embryology, purple sea urchins are often wild-caught, which can end their 70-year lifespan prematurely. Students place sperm and eggs on a slide, observe fertilization and the early developmental stages through a microscope, as a mandatory procedure in many North American high school and undergraduate biology classes. What is missing entirely in this performance of vivisection are ethical and attendant philosophical and psychological reflections on witnessing the miracle of new life, which then is merely washed down the drain at the end of the lab period. In this case, the dominance of the human species over all other beings is unquestioned and is an unquestionable assumption. So is the conception that our benefit eclipses the need and suffering of nonhuman species. The speciesism embedded in science curricula, and the definition of what is sentient or even alive, seem to have been completely unnoticed, let alone challenged.

However, as our narratives below will show, many young (and not so young) people experience their relationship with other life forms differently: with genuine love and respect, with empathy and care. Thus, their experience in the biology lab is often alienating and traumatic.

7.2 Killing the Wonder: Three Biology Lab Narratives

A Study in Life
by Lee Beavington

My trembling fingers inject the needle into the mouth of the sea urchin. The needle point is reluctant. I push the point until it slides deep into the soft tissue, then inject the potassium chloride, the same that Dr. Kavorkian used to stop melancholy hearts. But I am not after death. I am after gametes, the fruit of life. Will it be egg or sperm?

Under the microscope in the biology lab, first-year university students witness that most miraculous genesis called fertilization. A frenzy of sperm compete for a single egg. Of the millions of flagellated vessels of DNA, but one obtains that golden prize. My job, trumping my conscience, is to provide the fertile ingredients; students then play god on a microscopic level.

I watch the injected urchin before me. Is this sea hedgehog older than I? At first, the echinoderm offers no response. Then, slowly at first, its spines begin to undulate. An involuntary response that I perceive as a silent plea for help. In one final humiliation before the scientist, I place the urchin upside down over a beaker to allow gravity to collect the gametes.

Amber spheres emerge and drop into the safety of the beaker's saline solution. Eggs. A female. Somehow, this feels like a greater evil.

Once I have collected both ova and sperm, and placed them in the refrigerator like reproductive fast food, the lesson can begin. The young women are squeamish at having to carry sperm smeared on a slide. The young men poke fun at them. Magnified four hundred times, the sperm resemble vibrating carrots, while the eggs are solemn planets waiting to be colonized.

Most of the eggs reject sperm. Late autumn is not their usual season for fertility. Those that are receptive balloon outward, building a fertilization envelope to prevent subsequent suitors. This one cell divides into life. First into a berry-like morula, then a hollow blastula and—like a good model organism—all the same embryonic stages of a human baby. The students follow this development over the course of a week, when some of the virginal urchins start to move. Then they are washed down the sink.

My students have contrived life, acting as laboratory midwives, only to abort the urchin embryos once they look like something alive.

At the next biology meeting, surrounded by a dozen colleagues, I indicate that I have something to add to the agenda. "I cannot be involved in any activity where I consciously kill an animal."

Silence. Will my request be scoffed at? Will I be ridiculed for contemplating the life of lowly urchin? Have I threatened my job? The department chair sits to my right. Under my clammy but steady hands lies a folder with my next move, should I need it: a letter to the Dean of Science outlining in clear and concise terms my refusal to end life in the lab. Finally a fellow lab instructor says that he understands my request and is fine if I excuse myself from those activities. A brief discussion

ensues. I sense others are uncomfortable with injecting the urchins, but they hesitate to agree with my position.

I leave the meeting relieved yet unsettled. I no longer have to compromise my conscience, at least not directly. I walk out of the lab, past the tarantulas, stick bugs and budgies, hermit crabs and hissing cockroaches, each in their own neat little cage. Finally, the saltwater tank with the purple sea urchins. There are five less than before. I watch the remainder in wretched triumph, waving their spines in a tender tremble.

Aristotle's Lantern

blackhole mouth bares sea-shorn teeth
midnight raises her five-fanged pyramids
her radial world balances the tide
as she churns kelp to weed and rock to sand
she keeps the seafood chained

without eyes the urchin holds the sea
perception starbursts beyond her calcite shell
a skeletal test for otters to best
consumes this ecosystem engineer
her mouth made for seaweed

she nurtures the nocturnal intertides
her roving dome an outward panopticon
perhaps this urchin is a philosopher
with senses no mammal possesses
in phase with every rippled wave

what did Aristotle see
when he was entranced by her spines?
that entrance to a geometric jaw
simple mechanics or a radiant threshold
window into the urchin universe

the only law she abides is natural law
a reciprocal rule we have forgotten
to her wisdom we are blind
if we held her lantern high
what question would she ask of us?

Encounter with Horror and Absurdity
by Heesoon Bai

My encounter with senseless killing and suffering took place more than four decades ago, during my teen years in Korea. It was in my biology class. My school, a top academic secondary institution in Korea, was delivering advanced academic courses

to students. As part of such advanced modern (read: "westernized") curriculum, we performed vivisection. Thus, one day, I was faced with live frogs, rendered senseless with chloroform. There were some sixty of us in the class, and there must have been close to 100 frogs. I have no memory of exactly what it was that we were studying in frogs. All I remember is the sight and smell of a whole heap of frogs, whose chests and bellies were opened up, still breathing and palpitating. And that was the end of their short lives: no suturing, no bringing them back to life, just thrown in the garbage after our lab session. At this sickening sight of senseless killing of creatures, I was plunged into existential horror and despair. I loved little creatures! I was friendly towards them, played with them without hurting them, and rescued them if they were in trouble. This was an experience of deep wounding in my heart and soul. And it also illustrated for me what biology was, in the way this subject matter was conventionally taught: it certainly did not promote love of life phenomena.

Decades later, when I was teaching undergraduate and graduate students at my current university, I met quite a few students who told me that they went into biology because they loved life phenomena, but after studying biology (some of them graduating with a major in biology), the love of creatures they experienced throughout their growing years evaporated, and they were sorrowful about this loss.

We choose to study something because we love it; but in the process of studying, we often kill our love. The conclusion to be drawn here is not that study kills. Rather, we need to be aware of what studying may entail. There are different ways to study or research. I am reminded of the comparison that is made, by Erich Fromm (1976), of three poets whose contrasting worldviews and approaches to life phenomena illustrates different ways of studying. Lord Alfred Tennyson (1809–1892), Basho (1644–1694), and Goethe (1749–1832) are the three poets in reference here. I quote their respective poems:

First Tennyson:
Flower in a crannied wall,
I pluck you out of the crannies,
I hold you here, root and all, in my hand,
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is

Next, Basho:
When I look carefully
I see the
nazuna
blooming
By the hedge

And lastly, Goethe:
I walked in the woods
All by myself,
To seek nothing,
That was on my mind.
I saw in the shade

A little flower stand,
Bright like the stars
Like beautiful eyes.
I wanted to pluck it,
But it said sweetly:
Is it to wilt
That I must be broken?
I took it out
With all its roots,
Carried it to the garden
At the pretty house

Now, Fromm's (1976) comments at length on the three different, what we may recognize as, research paradigms:

> *The difference is striking. Tennyson reacts to the flower by wanting to have it. He "plucks" it "root and all." And while he ends with an intellectual speculation about the flower's possible function for his attaining insight into the nature of God and man, the flower itself is killed as a result of his interest in it. Tennyson, as we see him in his poem, may be compared to the Western scientist who seeks the truth by means of dismembering life. …. What Basho wants is to see, and not only to look at the flower, but to be at one, to "one" himself with it—and to let it live. … For Goethe the flower is so much alive that it speaks and warns him; and he solves the problem differently from either Tennyson or Basho. He takes the flower "with all its roots" and plants it again so that its life is not destroyed. Goethe stands, as it were, between Tennyson and Basho: for him, at the crucial moment, the force of life is stronger than the force of mere intellectual curiosity. Needless to say that in this beautiful poem Goethe expresses the core of his concept of investigating nature*. (pp. 14–16)

Is one paradigm more biophilic than another?

The Earthworm Protest
by Serenna Romanycia

When I was a child, I had many friends. They lived in deep green forests with mossy carpets, hot sun-bleached meadows filled with buzzing crickets, mysterious lakes, scummy warm ponds, and many other places. The particular friends I speak of in this story made their home in cool, nourishing soil: the earthworms. Sometimes, when my family would garden together, I'd encounter them suddenly unearthed, writhing and wriggling to get back into the safety of the ground. At other times, on rainy nights, I'd go for a walk and find them rain-bathing at the edge of the sidewalk. They'd be stretched out long, half in the grass and half on the pavement, perfectly still. One vibration from my footstep, and they would pull back instantly, disappearing in a heartbeat underground.

Yes, my earthworm friends were very sensitive, peaceful creatures, and they didn't particularly enjoy bright, exposed spaces. But sometimes, in the daytime, if it was rainy, I'd find them out and about, wriggling along at a speedy pace to some destination. I've read that worms travel in the rain, as it gives them an opportunity to travel along faster than they would through soil. But it seems to me that there's more danger in this method of travel, too. When I attended middle school, I spent a

good deal of time at lunch patrolling the track and the sidewalks, where on rainy days my travelling friends would often be squished by careless or cruel kids, drowned in puddles, or run over by cars. A few of my human friends would help me in my efforts to save earthworms. We would run around and gather up all the worms that were stranded on the pavement or getting washed down the storm drains, and put them back into the soil around the school grounds.

I must confess my friendships with the earthworms, in fact with all of my animal friends, somewhat changed as I entered high school. I still considered them my friends and never lost my connection to and love of the wild. However, my attention was rather diverted to navigating human teenage culture. Most of my time was spent with human friends. I stopped making a concerted effort to save my old earthworm buddies at the track, and instead made a concerted effort to deal with fluctuating hormones, fluctuating friendships, and fluctuating grades. Yes, I must admit that earthworms were the last creatures on my mind.

Yet, an incident brought my old friends back into my heart, with a shocking jolt. Scene: science class, block before lunch. Me: sitting in the back row, angry. The teacher had just passed out beakers filled with some liquid. I gripped my beaker, feeling sick: here were a few of my old friends, floating around anesthetized, still barely alive, but numb and motionless. We were told we would be dissecting these "specimens"as they were now "slowed down" enough for us to study and learn about them.

Specimens? No, these weren't specimens! They were little living beings! They were my friends, and I was going to be damned before I cut them open alive to "learn" about some scientific fact that was also written right there in the textbook. I told the teacher this, which provoked laughter from my classmates, but a tinge of respect too. I looked around and saw several kids with the unmistakable uncomfortable look on their faces that so often reveals when our internal moral compasses get overridden by convention and pedagogy. It felt wrong, and that wrongness registered physically in my gut: a clenching, sickening, clammy sense of people being blind to the suffering and broken dignity of other living beings. My teacher told me firmly these were "just worms," and it was stupid to feel sorry or compassionate towards them. "Yeah," piped in some taunting kids: "It's not as if worms have brains, hearts or souls!"

I refused to participate in my classroom experiment on grounds that it was unethical, disturbing, and completely useless, revealing "information" that could easily have been found on the internet, as it was a high school experiment that had been performed thousands of times. The teacher responded angrily by docking me marks and offering other classmates higher marks if they would in fact eat a live worm. (I believe some of them actually did, if my memory serves me correctly.) Others, like myself, continued to boycott the experiment.

I still hear the kids' taunting: "It's not as if worms have brains, hearts or souls!" How ironic that they should say that. Worms actually have five hearts, and a "brain" that is a nerve cord that runs the length of their body (not a vertebrate brain); and I suppose it depends on how you define soul, but they certainly possess life energy that flows through them and responds to the world and the challenges to their sense of well being, just as does every other living being on earth. What was really stupid, I told my teacher, was that we were killing these creatures to "discover" and "study" them, but in doing so we were destroying what was actually of value to

learn: the joy and mystery of how these creatures live their lives. I was sure I knew more about earthworms just from hanging out with them in my garden, saving their lives on my middle school track, and stepping around them carefully on a rainy night walk. These were all the times when my powers of "observation" were not detached from my relationship to the creatures themselves. Let us consider: how do we really get to know other people best? Is it by capturing people, drugging them, putting them in captivity, slowly cutting them open and demanding they reveal something to you about the nature of truth as they die? Or is by spending time together, eating food together, sharing good memories, stories, laughter, joy and tears, and developing emotional connections and loving relationships?

I hope the answer is obvious to my readers: it is the latter. The next question is then: why should this answer necessarily be any different if it is posed towards a member of a different species? I believe that, just like humans, other creatures should not be treated as objects to be used, experimented on and disposed of. And, just like studying humans, there are many other ethical alternatives to learning-about other life forms than capturing them and putting them under a microscope or a scalpel. We are vastly lacking an ethical-ecological framework within the current scientific pedagogy that recognizes the intrinsic value of all living beings. I suspect my perspective might resonate with many readers, showing up as a stirring of the heart, a shared wish between living beings to live full lives and to be treated ethically and compassionately.

7.3 Goethean Science: Delicate Empiricism

The mainstream modernist western empirical science, based in Cartesian-Newtonian philosophy, is a worldview that postulated a mechanical universe devoid of sentience. In great contrast, Goethe's approach, known as *"zarte Empirie,"* meaning delicate empiricism (Wahl 2005, p. 58), was to know the thing-in-itself. His method observes with empathy and attentiveness, which can help reconnect us with our biophilic nature. Goethe explained that "[l]ife resides in wholes: when organisms are taken apart they are no longer alive. In order to understand, and hence engage with, the aliveness of nature, we have to understand it in terms of its wholeness" (Mathews 2008, p. 60). The Cartesian-Newtonian model of science obliges a positivist and mechanistic approach, whereby an organism is reduced to its individual components, which takes on primary importance. The breadth of biology covers subcellular components right up to the biosphere—and all levels of organization in between—yet lab dissections often completely omit this consideration. Students put on gloves, cut into an animal specimen, identify the individual mechanics, and finally discard the carcass. This anti-holistic attitude suppresses ethical and philosophical concerns, which can lead to an ontological reversal, whereby symbols and models are assigned greater significance than the actual phenomenon under study (Hadzigeorgiou and Shulz 2014). If "the search for a philosophy *of* science is imperative" (p. 1999), we need to find an appropriate approach to science pedagogy.

> The Goethean epistemology of conscious-process-participation does not negate the validity of reductionist science, it merely challenges its position as the exclusive source of reliable knowledge about the world and offers a way to overcome the limitations of the dualistic subject-object-separation epistemology. (Wahl 2005, p. 67)

Goethean science calls for contemplation, in which empathy and prolonged looking promote a participatory mode of consciousness. With reciprocity between the observer and observed, self and other, subject and object, this relationality elicits compassion and ethical consideration (Bai 2001; Bai 2004). Martha Craven Nussbaum mentions that for Aristotle "all animals are akin, in being made of organic materials; humans should not plume themselves on being special" (Nussbaum 2006, p. 348). This kinship is too often lacking in science education, where microscopes, scalpels, and needles become tools of separation. Michalinos Zembylas (2004) has explored the importance of emotional labor in science, where reason outweighs emotion, and suggests that learning science through emotion can allow us to follow students' interest and excitement.

Aesthetic and contemplative practices can help transform science education toward a more integrated curriculum. For example, rather than entering a lab where sea urchins have already been probed and their gametes extracted into beakers, students can be given an opportunity to understand the natural world of the sea urchin. How do they survive in the harsh intertidal environment? How do they fit into their environment, and in what ways do they affect the ecosystem? How might their perceptions of the world differ from ours? These types of questions can be explored through narrative, artwork, poetry or self-reflection. In studying earthworms, their outdoor habitat or even a well-maintained compost can be used so students can experience these annelids directly: recognizing the earthworm's essential need for a moist environment as it relates to support and their permeable skin, gently feeling their segmented movements, and discussing its important role as a detritivore in soil aeration and in recycling organic materials. Such activities, similar to the WormWatch program offered by NatureWatch in Canada, cover science learning objectives without the need for dissection.

Teaching respect for all life should precede any biology education. Our species' survival depends on pollinators, photosynthesizers, and bacterial digesters in our gut; to foster an ecocentric worldview we need a foundation that gives intrinsic value to all life forms. To this end, for example, a creative writing exercise may be undertaken with students to help cultivate this respect. The lesson plan is simple: students employ multiple senses to engage with an item from nature. Preferably, such an item is discovered by students' themselves, led by their own curiosity while exploring the natural world. Students then brainstorm key words, ideas, and make drawings or other art inspired by this sensory engagement. From these inspirations they are given space to write a short story, poetry, or personal reflection essay, either on-site or at a later time. This pedagogic activity follows Goethe's approach, where creative and artistic expression is inspired by receiving from the object under study, thereby having students learn both *about* and *from* nature. With such reciprocity, animal neglect and cruelty are less likely to be tolerated. If we want to respect and honor all life phenomena and cultivate reciprocity, we need to open our hearts to an alternative paradigm that considers humans to be but one species among many in the vast cauldron of life.

A Conversation Between Sea Urchins

Specimen Species

I hear rumours of a sea beyond measure
whose borders slide with the moon.
Tell me of the ocean

Every wave delivers life,
the ebb brings barnacles and sunlight
the flow—fresh intertidals and brine, the world
in constant motion

All I perceive is a glass cube
that ends with the researcher's budget

Do you not see the world
in every direction, every
current from sediment to sky?

I have a filter and lab technician,
my body is an experiment.
What I fear is fertilization day
when what they call the Kavorkian needle
prods my gonads

Imagine such a way to release life
there must be a reason you were chosen

I heard them call me a "model" organism

A model for what?

A model to be cut, probed, vivisected
until every gene has been sequenced
and each eye to every microscope satisfied

Were you born in a lab?
When do we stop
being urchins?

Humans and urchins are kin,
my embryos resemble humans

So being similar causes you suffering

Being different causes my suffering

You said we come
from the same place

But I'm not human enough

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