COMMENTARIES

Natural History and Ecology: Three Books You Should Read (and a Few More)

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Anderson, J. G. T. 2013. *Deep things out of darkness: A history of natural history*. University of California Press, Berkeley, California, USA.

Eisner, T. 2003. *For love of insects*. Harvard University Press, Cambridge, Massachusetts, USA.

Hardy, A. 1967. *Great waters: A voyage of natural history to study whales, plankton and the waters of the Southern Ocean.* Harper Collins, New York, New York, USA.

Before there was ecology—much before, many centuries before—there was natural history. Thirty thousand years ago, people painted aurochs, horses, rhinos, and other animals on the walls of caves, and painted them very accurately and with much insight. In a famous painting at Chauvet, which contains some of the oldest cave paintings, the heads of a herd of horses are set at the angle of a gallop and their mouths are open as if they are breathing hard. The pelage of painted horses in another cave at Pech-Merle, France, matches known phenotypes and genotypes of predomestic horses (Pruvost et al. 2011). These people were keen observers of nature. They wondered about it. Their attempts to communicate that wonder to their peers were the joint birth of natural history and art. As John Anderson says in his comprehensive account, natural history is the oldest of the sciences. This is the time when we became human. To be human is to wonder about nature, how it is put together, and our role in it. That wonder is the source of natural history, ecology, the rest of the sciences, and the arts.

Natural history is the foundation of ecology, but it was not until 1866 that Ernst Haeckel, one of Darwin's strongest supporters, coined the word "ecology." Neither Darwin nor any of his contemporaries, however, used the word. They referred to themselves as "naturalists." The word "ecology" was not widely used until well into the twentieth century, when naturalists such as Stephen Forbes and Eugen Warming began thinking about the more complex relationships between the organism, the population to which it belonged, and the different species and environment with which it interacted.

Ecological research in the early twentieth century still had a strong natural history flavor, emphasizing direct observations of organisms in their natural environments, especially their life histories. It let the observations suggest the questions and theories. As late as 1927, Charles Elton could open his book *Animal Ecology*, the founding treatise of the field, with the sentences: "Ecology is a new name for a very old subject. It simply means scientific natural history." But a few sentences later, Elton also says: "It is a fact that natural history has fallen into disrepute amongst zoologists."

So in fewer than 60 years since Haeckel coined the term, ecology seems to have begun shedding its relationship to its foundation. No longer were comprehensive studies of organisms suggesting the questions. Instead, questions emerged from increasingly abstract concepts, such as the niche, food webs, ecosystems, and, most recently, perceived societal needs and problems, such as ecosystem services. But there appears to be the beginning of a resurgence of natural history and what it contributes to these larger questions (Bartholomew 1986, Grant 2000, Greene 2005, Dayton and Sala 2001, Tewksbury et al. 2014). In particular, Tschinkel and Wilson (2014) have revived Elton's term "scientific natural history," the Ecological Society of America has a Natural History Section that is five years old, and in the past year, *Ecology* has begun publishing *The Scientific Naturalist*, a series of short papers on the natural history of organisms.

Given this resurgence, it is well to ask some questions: What is the history of natural history and how did it give birth to modern ecology? What core ideas, if any, has natural history provided to ecology? How is natural history done? Answers to these questions may help us understand where natural history is going and whether the natural history of the future will be different than it was during the Golden Age of Darwin, Hooker, Huxley, and Wallace. The three books reviewed here help us consider these questions.

The themes and ideas of natural history have changed over the centuries, as admirably documented by John Anderson in what may be the only comprehensive history of natural history. One of natural history's most important contributions to ecology is the relationship of an organism's anatomy to its life cycle and the environment it occupies. This foundational idea was developed by none other than Aristotle. For his books *Parts of Animals* and *The History of Animals*, Aristotle dissected many animals and observed their behavior in their natural environment (see also Leroi 2014). Although some of his interpretations of anatomy and physiology are faulty, the observations themselves are first rate. As Anderson notes, "one can dip into *The History of Animals* at almost any point and find a gem worth consideration and follow-up."

For reasons that are not clear, few people followed Aristotle's example of direct observation of the living world for more than a millennium, from Pliny up to the Renaissance. During Roman and Medieval times, the main theme of natural history was allegorical fable constructed to teach proper moral behavior of humans. All of this is bunk and it is hard today to understand why it lasted so long. The medieval world was a strange place, indeed. One of the few exceptions to this endless series of silliness seems to have been the thirteenth-century Holy Roman Emperor, Frederick II, whose masterpiece *De Arte Venandi cum Avibus* (*The Art of Hunting with Birds*) was, Anderson says, the first real treatise on ornithology. Indeed, Anderson says that Frederick was the first since Aristotle to emphasize "personal observation and experimentation." Unfortunately, no one continued in Frederick's tradition and natural history wallowed in magic and wizardry for several more centuries.

The world rapidly changes when we get to the seventeenth century. Anderson very perceptively remarks that the beginning of the seventeenth century "saw the staging of Shakespeare's *The Tempest*, featuring Prospero, almost the archetype of the medieval sorcerer–scientist. By the end of the century, Isaac Newton had published his *Principia*, John Ray and colleagues had moved botany out of the realm of the herbalists, William Harvey had demonstrated the circulation of the blood in vertebrates, and science and magic had parted ways once and for all." John Ray was one of the first to recognize that documenting the diversity of life was one of the core problems of natural history. This new emphasis on cataloging the diversity of life was prompted by the rapid pace of new discoveries of new worlds. Peter Kalm and Andre Michaux opened European eyes to the rich diversity of New World natural history and the microscopists Antonie van Leeuwenhoek and Robert Hooke began describing the almost unbelievable forms of life invisible to the human eye but that existed right under everyone's nose. In the eighteenth and early nineteenth centuries, Hutton, Buffon, Lamarck, and Lyell began to come to grips with the age of the earth, realizing that the earth is very very old. The great age of the earth and Buffon's realization that fossils are vestiges of former lives gave natural history a temporal dimension ("deep time") to match the expanding spatial scale of diversity across the globe.

Describing this diversity, one species at a time, and understanding its meaning became the central theme of natural history during the late eighteenth and early nineteenth centuries. Naturalists, led by Linnaeus, made great and lasting progress in developing a method of cataloging life that persists today. Linnaeus's system was a practical way to do natural history because it focused on specific anatomical parts, mainly for reproduction (genitalia) and feeding (mouthparts), by which closely related species could be distinguished from one another. Focusing on reproductive and feeding anatomy inevitably led to broader ecological thinking about population dynamics and food webs, two of the core problems in modern ecological thought. For example, Anderson relates how Ray began thinking about population dynamics by "suggesting that birds lay only the number of eggs that will maximize their reproductive success, rather than being limited by the ability to lay eggs," thus foreshadowing David Lack's research two centuries later. As naturalists described more and more species, it became apparent that these anatomical parts were adaptations to the environment the species lived in. In a sense, Linnaeus and his followers were not only fulfilling the program begun by Aristotle, but also expanding it into new worlds.

Linnaeus's system also organized organisms and species into a hierarchy of similarity, and so gave natural history a theoretical problem that begged to be solved: What were the natural mechanisms by which this hierarchy came about? This became the defining problem for natural history in the nineteenth century. Natural theology, founded by Ray himself, proposed that the hierarchy of Linnaeus's classification and the exquisite anatomical adaptations upon which it was based were evidence of God's beneficent creation.

And that is where things stood when young Charles Darwin set sail on the *Beagle*. Early on in this voyage, while the *Beagle* surveyed the east coast of South America, Darwin noticed that related species succeed each other vertically in the stratigraphic record exposed along the coast and horizontally across the pampas landscape and he began to wonder why this should be the case. This was perhaps the first clear statement of the core problem of biogeography, and it expanded natural history from simply classification and description to include the problem of the distribution and abundance of organisms, a problem later taken up in depth by Alfred Russel Wallace. This core problem of nineteenth-century natural history prompted Darwin's long odyssey to *The Origin of Species* and beyond. All of Darwin's books begin with a problem in natural history, and he remains the undisputed master of it. Many of his arguments and evidence for evolution consist of natural history observations of the adaptive traits of organisms. Darwin did not begin by trying to provide a biological theory underlying Linnaeus's hierarchical classification. Nonetheless, natural selection became the cornerstone of any theory of why particular traits define species, and why those traits are often adaptive. Darwin's other cornerstone of evolution, descent with modification, explained why Linnaeus's classification system is so naturally hierarchical. After Darwin, all serious natural history had to confront the evolutionary origins of the traits that define organisms and their relation to their habitat.

The *Beagle* followed James Cook's and Joseph Banks's voyages of exploration in Newfoundland and the Pacific. They were followed by many other voyages of discovery of the British Navy, including the *H.M.S. Challenger* (a survey of the ocean's depths, with Henry Moseley as naturalist), the *H.M.S. Rattlesnake* (a survey of Australia and surroundings, with Thomas Huxley as naturalist), the *H.M.S. Erebus* and the *Terror* (an early survey of Antarctica, with Joseph Hooker as naturalist), the *R.R.S. Discovery* (a survey of the Antarctic continent, with Edward Wilson as naturalist, and later a survey of the natural history of whales, with Alister Hardy as naturalist—more on this last voyage in a moment). Even though these voyages were done to give the British Navy something to do during *Pax Britannica*, more natural history may have been discovered during them than during any other period before or since. Unfortunately, Anderson covers only Huxley's and Hooker's voyages in a single chapter. For a more comprehensive view of the great British explorations by sail, the reader must turn to Iain McCalman's *Darwin's Armada*, a joint account of the *Beagle*, *Rattlesnake*, and *Erebus* and *Terror* voyages. A truly comprehensive account of the British voyages of discovery and their contribution to the natural history of the entire planet awaits its historian.

Darwin is clearly the apex of Anderson's book. After the Darwin chapter, Anderson discusses Alexander Humboldt, whose journals on the Amazon inspired Darwin to join the *Beagle* expedition. Anderson then races through single chapters devoted to Wallace and Henry Walter Bates, the American geological surveys under John Wesley Powell, Louis Agassiz and Henry David Thoreau in New England, and then a short chapter which covers John Muir's studies of glaciers in Yosemite through Aldo Leopold and the Kaibab Plateau, to Rachel Carson and the dawn of modern marine biology and environmental science. The book ends with an elegiac chapter on the decline of natural history after the turn of the twentieth century, which Anderson blames on the quantification of science and the move from the outdoors to the laboratories.

I am not so sure that natural history has declined during the twentieth century. Rather, it seems to me that it simply changed themes and problems as ecologists began to incorporate laboratory and mathematical approaches into their toolkits, just as Anderson's previous chapters showed how the themes and problems of natural history changed during the centuries since Aristotle and thereby helped shape modern science. Even though Anderson does not discuss them, Ernst Mayr's ornithological work in New Guinea, Theodosius Dobzhansky's field studies of native fruit flies, and George Gaylord Simpson's paleontological studies of the evolution of mammals in the New World had strong natural history components that grounded the Modern Synthesis of Darwinian selection and Mendelian genetics with observations of organisms in their native environments. Elton's *Vole, Mice, and Lemmings* is natural history at its finest, but it also brought the dynamics of population cycles to the forefront of ecology, where it has remained a major theoretical problem to this day. Barbara McClintock claims that her discovery of transposons was possible only because of her understanding of the natural history of maize, from the seedling to the adult plant (Keller 1984). Robert MacArthur is remembered mostly for his grounding of ecological theory in rigorous mathematics, but we should not forget that his ideas about competition and niche came from his studies of warblers in the Maine Woods, a paper still worth reading for its joint exposition of the life cycles of the members of this feeding guild (MacArthur 1958). In addition, MacArthur's work with E.O. Wilson on island biogeography (MacArthur and Wilson 1967) was motivated by Wallace's groundbreaking natural history of distribution and abundance (Wallace 1876), especially on island archipelagos. Wilson's grand tomes *Sociobiology* (1976) and, with Bert Hölldobler, *The Ants* (1990), are natural history in the great tradition of Darwin and Huxley. Unfortunately, most of these great books are no longer read, certainly not by our graduate students. Perhaps it is time to revisit these great works and examine in more depth how natural history grounds experimental and theoretical work.

In the meantime, Anderson's entertaining and informative history of natural history should be widely read to inspire others to make similar comprehensive studies of the evolution of natural history thought during the twentieth and prior centuries.

So how has natural history been done during the twentieth and twenty-first centuries? The other two books reviewed here demonstrate two different ways that natural history provides a foundation for modern laboratory and theoretical work. I find these two among the most enjoyable of all natural history books, and of most other books, that I have ever read.

One way to do natural history is in the classic nineteenth-century tradition of taking a walk in the woods, noticing things, and then zeroing in with more investigations to uncover what they mean. Darwin's later books after the *Origin* are mostly in this vein. Thomas Eisner was a modern-day master of this approach. He was the founder of chemical ecology, especially concerning how insects use chemical cues to communicate and to defend themselves. His *For Love of Insects* is a scientific memoir of his many encounters with insects and their chemical ecology. Every one of these episodes begins with a walk in the woods during which Eisner notices something intriguing. Eisner must have been a genius at this because many of us who pride ourselves on our ability to pay attention while immersed in nature would, I am sure, have missed making Eisner's observations or, having made the same ones, might have not pursued them with his diligence. What follows is a series of elegantly simple experiments culminating in the identification of the particular chemical or suite of related chemicals responsible for the observed behavior of the insect. Eisner's research program was to discover the molecular basis of the natural history of insects, or alternatively the natural history of bizarre carbon compounds. If your undergraduates hate taking organic chemistry, have them read this book first.

Eisner is perhaps best known for uncovering the chemical and anatomical defense mechanism of bombardier beetles. This adventure, which begins the book, began on a summer day in 1955 when he was crawling through a meadow in Lexington, Massachusetts, to see what he could find instead of writing his doctoral thesis. What he found were bombardier beetles, the same beetle that Darwin, as a student at Cambridge, famously popped into his mouth to free his hands to collect another beetle, only to have his mouth burned by bitter ejections. Eisner and Darwin had similar good taste in choosing insects while students.

After consulting with a colleague who was investigating similar ejections by the Uruguayan daddy-long-legs, *Heteropachyloidellus*, Eisner zeroed in on benzoquinones as the caustic agent in the ejections that are sprayed at the beetle's enemies from a posterior orifice. Benzoquinones are simple six carbon rings with two oxygens, each attached to a carbon at opposite vertices of the ring. These oxygens are released upon contact with tissues of the enemy and thereby provide the burning sensation. To learn more about what happens during the ejection of the benzoquinone, Eisner embarked on a series of experiments that never wandered very far from the natural history of the bombardier beetle. Along the way, Eisner invented simple but very effective experimental techniques. For example, to document the pattern of the spray exiting the glandular duct, Eisner coated filter paper with a slurry of starch, potassium iodide, and hydrochloric acid. The coated paper turns brown when oxidized by benzoquinone. After the paper dried, he placed the insect on it and, after pinching it in various places, discovered that the beetle can aim its spray toward the offender with uncanny accuracy by rotating the orifice "gun." He noticed that the ejection was accompanied by rapid pops and, after making a spectrogram of the sounds, learned that the spray is ejected very rapidly in pulses that last microseconds. He then hooked up a microphone to a rapid-fire flash unit. When the beetle ejected the spray, each pop was picked by the microphone, the flash was discharged, and the pulsed spray was captured on film. One image of the beetle's "fireworks" was the cover photo of the 4 July 1969 issue of *Science*. Further improvements in his photographic techniques led to collaboration with Harold Edgerton, famous for developing high-speed photography to show that when a horse gallops there is a brief moment when all four legs are off the ground. The high-speed photography confirmed the rapid pulsing and accurate aim of the spray. These early forays in photography eventually led Eisner to become one of the premier photographers and videographers of insects—his film with the BBC about chemical defenses of insects won the Grand Award in Science at the New York Film Festival—and his book is lavishly illustrated with his extraordinary color photos.

How, Eisner then asked, does the beetle exert such precise control on the timing of these pulses? Research by others had demonstrated that precursors of benzoquinone are stored in an upper reservoir chamber of a posterior gland. When the insect is attacked, these are discharged into a lower reaction chamber where enzymes catalyze their reaction to produce benzoquinone, which is then excreted through the orifice "gun." Careful dissection by Eisner revealed a tiny valve that separates the upper chamber of the gland from the lower. Eisner explains it best: "To initiate an ejection, all the beetle needs to do is compress the [upper] reservoir. When the resultant pressure overcomes the occlusory force of the valve, [the precursors] are expelled into the reaction chamber, initiating the explosion… As the temperature and pressure rise, the valve is forced closed, resulting in a further rise in pressure…causing its contents to shoot out. With the chamber emptied, its internal pressure is restored to a level lower than that exerted on the [upper] reservoir [by the still contracted muscle] and the cycle promptly recommences and will continue to repeat itself as long as the [upper] reservoir is compressed [by the muscle]."

Other chapters describe similar series of experiments with other insects. I describe this one on bombardier beetles in detail to show how Eisner's entire research plan was not laid out in advance. Instead, he let the natural history of the organism unfurl step by step, each step suggesting what needs to be done next and what equipment was required. I began using this approach a number of years ago and it has certainly made my research more fun.

Great Waters is a scientific memoir of the last of the great British voyages of discovery by sail on *R.R.S. Discovery* during 1925-1927 to the Southern Ocean, which are the summer feeding grounds of the last large stocks of baleen whales. The *Discovery* was the last three-masted wooden square-rigger built in Britain and was modeled after the Arctic whaling vessels built earlier. At the time, Britain still had a commercial whaling industry centered on South Georgia Island, the home port for the *Discovery* expedition. British scientists convinced the government that the industry would not be sustainable without a deeper understanding of the distribution and ecology of the whale stocks. Sir Alister Hardy was the chief zoologist overseeing all the work on plankton, krill, and whales, and integrating the data collected on the distribution of these organisms with parallel work on the chemistry and circulation of these waters. It is fortunate for us that Hardy kept a diary because the book was published in 1967 after he finished overseeing the publication of the thirty-four technical volumes of the *Discovery* voyage. *Great Waters*, written in beautiful, classical Oxford prose, is a synopsis of the important scientific findings of this voyage wrapped in an adventure story that was never again repeated as steam and later diesel replaced sail.

Unlike Eisner's approach of taking walks and turning over rocks to see what he could find, the focus of this research was clear from the beginning. In the British tradition of voyage literature, Hardy spends the first 50 pages describing the history of the whaling industry and the meetings of the scientists made before the ship embarks. This is interesting because it was in these meetings that the problem was clarified, the holes in our understanding of the ecology of whales and plankton were identified, and the necessary equipment, including a continuous plankton recorder invented by Hardy, was developed. When the *Discovery* sailed on Thursday, 24 September 1925, the entire crew knew where they were going and what they were going to do when they got there. Their charge was to collect data on the growth, diet, and distribution of whales in the Southern Ocean around South Georgia Island in relation to the distribution of water chemistry and currents, phytoplankton, and zooplankton. No hypotheses, but still clear intentions of what to observe and why, spelled out in the subtitle: *A Voyage of Natural History to Study Whales, Plankton and the Waters of the Southern Ocean.*

The core science is contained in three key chapters: Whaling and Whale Research, The Knowledge Won, and Ideas and Speculations. It was fortunate that Britain had a whaling base at South Georgia Island because this gave the zoologists access over the two years of the expedition to no fewer than 1,683 whale specimens (over 100 of which were blue whales) that were being flensed for their blubber and meat. Hardy treated this as dissection on a grand scale. At the same time, he also showed some remorse that their data were being obtained by means of a harvesting operation that was clearly unsustainable, even cruel. This was the first solid dataset to calculate growth rates of blue whales, including fetuses and newborns. Growth is most rapid during the stages stretching from the late fetus on through birth and nursing, slowing only during weaning at about 18 months after conception. Astonishingly, there is no change in growth rate from the fetus to the newborn, despite an enormous change in the thermodynamic environment after birth. The fetus is protected from the cold by the great size and thick blubber of the mother, growing seven meters in twelve months after conception. To sustain this rate of growth, the mother's milk fed to the newborn during the nursing period had to be energetically very rich, especially because the frigid waters draw heat away from the newborn. The consequence of this change in energy balance is that the mother needs to feed on organisms that are abundant, densely concentrated, and energy rich. These requirements are fulfilled by *Euphausia superba*, the krill.

In addition to these shore-based studies, the expedition also sampled the distribution of water currents, temperature, phosphate, total phytoplankton, the major diatom species, the major copepod, mysid, and amphipod species, *Euphausia*, and fin and blue whales at 435 stations around South Georgia. I have no doubt that a paper submitted with similar data buttressed by GPS locations and geostatistics would be accepted for publication today in *Ecological Monographs*. To think this was done from a square rigger with a primitive research steamship accompanying her boggles my mind. Most importantly, the first quantitative description of a trophic cascade was assembled from these data. Where algal densities were high, phosphate concentrations were low, and vice versa, indicating that algae were controlling phosphate concentrations. Similarly, where zooplankton densities, especially the krill, were high, algal densities were low. Hardy first played with the idea that perhaps the algae were secreting noxious substances to protect themselves against the krill. Eventually, he settled on the conclusion that krill controlled algal densities and indirectly phosphate concentrations.

What about the distribution of whales? Are they the inverse of the krill, thereby extending the cascade one trophic level higher? Actually, the distribution of whales matches that of the krill. This means that the krill are controlling both the distribution of the algae (by consuming them) and the distribution of the whales (by feeding them). Top-down (to the algae and phosphate) and bottom-up (to the whales) controls emanate from the krill, making them the keystone species in this food web. Hardy did not use the terms "trophic cascade" and "keystone species," but they are clearly what he is describing fifty years before these terms were invented by Steve Carpenter and Robert Paine, respectively.

It is a wonder to me why the *Discovery* voyage and the thirty-four superb technical reports assembled under Hardy's supervision are now barely mentioned in ecological circles. *Great Waters* is out of print, as are the *Discovery Reports*, but they are well worth searching for on used-book websites. One of the charms of *Great Waters* that make the search worthwhile is Hardy's many superb pencil and ink drawings and watercolor paintings (watercolor! in freezing temperatures! on a rolling ship!). A number of years ago, I happened to be at a conference in the Zoology Building at Oxford, where Hardy became Linacre Professor of Zoology after his return. Hanging in the hallways were many beautiful drawings and paintings of marine plankton. It took me a while to recognize that these were Hardy's originals from this book and from his magisterial book on the natural history of marine creatures, *The Open Sea* (also out of print, but also worth finding). A colleague who was at Oxford more recently told me that these drawings and paintings are now in storage. The 100th anniversary of the *Discovery* voyage is coming up in fewer than 10 years. Perhaps Oxford could sponsor a show of Hardy's art and Oxford University Press could reissue a new edition of *Great Waters* to celebrate the occasion, to showcase the beauty of Hardy's art and his prose, and to restore this great expedition to its rightful place in ecology.

Anderson relates the story of a local man on the Orinoco River asking Humboldt, "How is it possible to believe that you have left your country, to come and be devoured by mosquitos on this river, and to measure lands that are not your own?" Why, indeed? Why do natural history?

One way to do biology is to search for the organism that is ideally suited to solve a problem (Tschinkel and Wilson 2014). This leads to the model organism (or model community or ecosystem) approach to ecology in which only a few aspects of an organism are studied in detail, usually to test a hypothesis. On the other hand, Tschinkel and Wilson say, "The naturalist does not ask what problem in biology his subject might solve. He asks simply what the species can tell him." Natural history does not start with hypotheses but with organisms. Nonetheless, following organisms wherever they take us reveals patterns not predicted by theory. It is my belief that all good lines of research in ecology and in almost all of biology begin not with hypotheses but with natural history observations (Pastor 2016). The hypotheses come later, often much later, after much patient observation. The history of natural history as recounted by Anderson, as well as the detailed memoirs of Eisner and Hardy, documents this again and again. Natural history generates hypotheses when we know which observations and which patterns of organisms are worth pursuing. To do that, we must acquire what Barbara McClintock called "a feeling for the organism." This takes much time and patience and not just a willingness to be devoured by mosquitos but to begin to observe and wonder about the mosquitos themselves.

Such a procedure does not fit the detailed, thought-out-in-advance experimental design format required these days by proposals to granting agencies, nor does it fit the Methods-Results-Discussion format of almost every journal. If we are to restore natural history to its important role of the discovery of unanticipated but important phenomena, then granting agencies, journals, and reviewers must loosen their grip on proposal and paper format.

The naturalists who are the subjects of these books went about their work with great joy. That joy may be what also inspires many naturalists, most notably Eisner and Hardy, to also be artists. Imbibing this joy is what makes these books such fun to read and reread. This is not to be discounted, for to quote Barbara McClintock again, “When you have that joy, you do the right experiments. You let the material tell you where to go and it tells you at every step what the next has to be because you’re integrating with an overall brand new pattern in mind.” Perhaps this is the deepest and best reason to do natural history.

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