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Michelle M. Francl
Bryn Mawr College

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Practically Impractical: Contemplative Practices in Science

Michelle M. Francl
Bryn Mawr College

Contemplation has been described as a "long, loving look at the real," a characterization that could equally well apply to science. In this paper, I frame a contemplative approach to the teaching and practice of science which draws strongly on the Christian monastic traditions. Students, in particular, struggle with the ever increasing information density in their course work which can cloud their understanding of the relationship of their work to broader contexts. I suggest that the monastic counsels of intentional simplicity, deep listening and constancy can provide a foundation for the design of science courses which help students engage more deeply with their work in the midst of a deluge of information, particularly visual and graphical information. I present four different contemplative practices suited for use in the scientific classroom and research lab: a simple, discreet stilling exercise for focus and attention, a 'beholding' approach to exploring visual data and two writing exercises designed for laboratory researchers.

Contemplation and science are often placed at opposite poles, one affective and passive, the other objective and active. We suppose scientists to deal in the objective, using methods that seek to subdue the personal and subjective. We have a strong image of scientists as balanced on the balls of their feet, wrestling with the materials of the universe; or, more distressingly, we see science as a place where "men backed nature into a corner and beat her secrets out of her" (Ehrenreich & English, 1978, p. 152). The pervasiveness of this image is well captured in the "draw a scientist" test, which asks respondents to sketch a picture of a scientist. The instrument elicits a remarkably uniform response. The vast majority of people of all ages draw figures in lab coats standing at a lab bench full of arcane equipment, juggling test tubes and flasks, with-out-of-control hair (Chambers, 1983).

In contrast, we imagine contemplatives taking up the transcendent and the immanent, through methods that are intensely personal. Nature is left undisturbed, her secrets safe. An analogous "draw a contemplative" exercise might yield images similar to those uncovered by a search-engine image search for "contemplative": peaceful, composed figures sitting still on cushions or balanced on one foot, unencumbered by attachments—and bald.

Our present society struggles with this conflict between science and the transcendent, a tension between seeing the world as a collection of objects that can be bent to our purposes and beholding the world as infinite and unknowable. At its very heart, my field of quantum mechanics wrestles with this dichotomy. How is it that matter—the stuff that surrounds us and *is* us—behaves as both discrete particles and infinite wave forms? My work as a quantum mechanic requires at the very least an implicit recognition of our fundamental inability to know everything with certainty: an acknowledgement that we dwell in a cloud of unknowing, that we cannot be separated from our experiments.

I would like to begin by arguing that "contemplative scientist" is not an oxymoron, but that these two approaches to engaging the universe can, should, and do pull in tandem. Next I ask what value a contemplative stance might have to the teaching and daily practice of science, and, perhaps more radically, I ask to consider explicitly embedding contemplative practices in the science classroom and research laboratory. Which core contemplative principles might be fruitfully brought to bear on curricular design? What are the benefits of contemplative approaches for the practicing scientist? Finally, I include a sampling of practical exercises drawn from these apparently impractical contemplative underpinnings.

While I want to make a pragmatic case that contemplative practices are useful tools for scientists, like the instrumentations, models, fact bases, or epistemological frames we use, I hope, more critically, to broaden the set of tools that we provide for nascent scientists, offering them not only ways to work better but ways to reflect on their work in relationship to the larger world.

Contemplative and Scientist

While "contemplative scientist" might now seem to be a contradiction in terms, it surely was not for Gregor Mendel. The 19th-century Augustinian monastic and physicist, certainly supported by his own and his community's contemplative practices, carefully contemplated the ways in which flowers passed traits from generation to generation, and so built the foundations for modern genetics. Such figures are not unique to earlier times. The current abbot of the Benedictine abbey of Saint John's in Collegeville, Minnesota is John Klassen, O.S.B., a published organic chemist. Jesuit brother Guy Consolmagno, S.J., has written more than a half-dozen popular books, including *God's Mechanics* (2007), a study of the religious perspectives of scientists and engineers, and over 100 scientific papers on planetary science—and retreats for a week each year in contemplative silence. Elizabeth Lund, PhD, has a faculty position in chemistry in Canada, taken up after spending a decade as an ordained Buddhist nun in Thailand. I move from chanting Lauds with a group of Augustinian monks at 8:30 each morning to talking to students about quantum mechanics by 9:00.

Despite a rich set of examples of scientists who are inarguably contemplatives, I suspect we are most comfortable imagining that their work as scientists and their "work" (if we wish to call it that) as contemplatives are independent of each other. Yet my experience is that the mindset I have when I chant in chapel or sit in meditation at night is not fundamentally different than the stance I take in either the classroom or my research work. Science is way of looking deeply into the universe. It is not so much a collection of facts or techniques as it is a way of painstaking reflection.

The Impractical: Some Principles for Contemplative Teaching and Research

My own contemplative practice centers my work both in the classroom and in the research arena. It is grounded in sixteen centuries of Christian contemplation, beginning with the fourth-century desert solitaries who, about a hundred years before Zen Buddhism emerged in China, fled cities and towns along the Mediterranean to practice meditation and a stark simplicity of life in the Egyptian desert, breathing in the transcendent. I am trained in the 500-year-old Ignatian tradition, the core of which can be tidily encapsulated as "contemplation in action," and formed by longtime practice with a local Augustinian monastic community.

The Ignatian way fosters and values an awareness of the daily and the present moment, as well as the expectation that right action will emerge from such a practice. The Augustinian tradition, a monastic practice drawing from rules of life set out by St. Augustine in the fourth century and St. Benedict in the sixth century, sharpens the ability to listen to specific voices within a community as well as to the unified voice of a community. Both traditions are formulated within the so-called evangelical counsels, which privilege the virtues of poverty, obedience, and chastity.

How do the principles that undergird my personal practice play out in the context of my teaching? While the taking of vows of poverty, chastity, and obedience sounds a faintly intimidating medieval tone, I would argue that these stances can be fruitfully reframed, at least for this 21st-century professor.

Poverty as Intentional Simplicity

How does my teaching change by conceiving of poverty not as having less than what I need but as a deliberate simplicity with regard not just to material things but even to the construction of a course of study? The 16th-century Basque contemplative Ignatius López de Loyola, who founded the Jesuits, a Christian order of religious men known for their educational mission and erudition, prefaces his *Spiritual Exercises* with the caution, "For it is not much knowledge that fills and satisfies the soul, but the intimate understanding and relish of the truth" (Puhl, 1951,

p. 2). There is, I believe, a value in intentionally restricting the amount of material I place in the classroom, even as the information available to us in these times is a torrent compared to that accessible to Ignatius.

As our fields grow, we are tempted to cram more information into our core courses. My own discipline of physical chemistry is no exception. The text my mother used in 1954 is half the length of the text I use today, but the number of semester hours devoted to the area is the same, and I suspect the capacity of our students to integrate complex mathematical material has not increased either. Yet we often subscribe to a vaccination model of curricular development. We include additional topics so "they will have seen it." Does a vaccination model work in science? Do students who have "seen" a topic recall substantive details about it? Do they remember seeing it at all?

In 1984 Hendrickson and Herbert reported the results of an experiment exploring the relationship between information density—how much was covered in a single course—and comprehension. Students were placed in one of two sections of a biochemistry course in a medical school. One section had the standard course, which covered a large body of material. The second section covered less material, but the syllabus was crafted to cover only the core principles. Both sections took the same final examination. Students in the informationally impoverished course scored significantly higher on the final exam. The other section may have "seen" more, but they did not retain more by this measure.

While there are other examples of the same phenomenon to be found in the literature, this is the one that speaks most powerfully to me, as medical students excel at mastering large bodies of information quickly. Poverty in the classroom might look like this: teach less, and they can learn more.

A stance of simplicity also supports a patience with silence in the classroom. Every second need not be filled with either me or my students speaking. Finally, it argues for assigning a reasonable amount of reading, particularly for technical material. Fifty pages of novel, highly technical reading takes roughly four hours to read once. I am careful to point to areas of the text where I expect close reading and other areas where skimming is acceptable, and to be attentive to the total time students will have to devote to the readings.

Lowering the information density in the classroom in any (or all) of these ways offers an opportunity for increased reflection: say less, and they can think more.

Obedience as a Deep Listening

The Latin roots of the work *obedience* are *ob* and *audire*: to listen deeply. An obvious facet of this virtue in the classroom is a willingness to listen to my students, not just to their superficial desires (fewer problems that require application of the product rule for differentiation) but to their deeper needs: to consider, for example, why they are taking this class, beyond the fact that it is required for the major. Less evident might be the ways in which I listen to the world outside my classroom. My commitment to teaching from a contemplative stance unfolds into teaching a context-rich curriculum, one which directly addresses the connections—the lines of communication—between chemistry and the everyday, as well as between chemistry and cognate fields.

For example, the decomposition of dinitrogen pentoxide is featured in most physical chemistry texts of the last century as an iconic example of the reactions that follow first order kinetics. The reaction is otherwise of little interest to chemists. It was originally done because the researchers wanted to put a new instrument through its paces and gaseous dinitrogen pentoxide was readily available in their laboratory (Daniels & Johnston, 1921). Could I teach the same fundamental concepts but simultaneously place them in a richer context?

Consider that the racemization of amino acids, in which nature's preferred left-handed form converts to the right-handed structure, is a slow process that also exhibits first order kinetics. Archaeologists use the process as a clock in the same way that carbon-14 is used, to find the age of materials that contain proteins. It's a long clock, enabling archeologists to probe time frames that carbon-14 dating cannot (Brooks et al., 1990). Conservation biologists have used the reaction to establish the ages of individuals within a population, discovering, for example, that bowhead whales have a lifespan of at least 150 years: important information for those managing resources (George, Bada, Zeh, Scott, & Brown, 1999). Substituting the details of this reaction for the iconic nitrous oxide work allows students to enter into a conversation with other fields and models for them the ways in which scientific work can extend beyond the walls of the laboratory.

Chastity as a Virtue of Trust and Constancy

The practice of chastity often evokes images of restriction and isolation, but when well-lived it provides a solid foundation for relationships. In my classroom practice, this presents as a clarity of expectations in both directions. Students can expect from me clear guidelines on the work and how I will assess it, and regular access to me for feedback between assessments. I expect students to come prepared, to engage substantively in the classroom, and to respect my time for other work. They can expect of me a constancy: I will not upend due dates or assignments without true need. I expect them to help each other and to help me.

One might argue that my way of being in the classroom, a way that is contemplative and intentional, is simply good pedagogy. I would not be inclined to disagree. But even the best classrooms are cloistered spaces, with a curricular plan and fixed beginnings and endings. Scientific research, on the other hand, seems to proceed at a rapid, dizzying pace down an infinite and winding road. Scientists have wild hair not in conscious imitation of Einstein but because they can't take the time to comb it. Surely to be contemplative in this milieu is to be left behind, perhaps far behind.

Yet I would suggest that there are practical benefits to being a contemplative scientist; that despite our image of the monk on a cushion, *contemplative* is not a synonym for *slow*. I believe that a contemplative approach to scientific research can (a) offer an antidote to the utilitarianism and reductionism that can restrict our vision; (b) counteract stress and encourage the sense of spaciousness that often accompanies ground-breaking discoveries; (c) develop a nonjudgmental eye; and (d) cultivate an ability to work with a wide variety of data, particularly the visual.

An Antidote to Utilitarianism and Reductionism

Some, though by no means all, philosophers of science hold that science encompasses more than what can be approached using the scientific method, more than we can capture by an enumeration of measurements and observations. Michael Polyani (1967), a twentieth-century philosopher and scientist, called this *tacit knowledge*: "We know more than we can tell." Chemists, in fact, often speak of bringing their "chemical intuition" to bear on a problem: their tacit knowledge, not necessarily captured in any set of chemical rules, of how molecules behave in particular circumstances.

Barbara McClintock, who won the Nobel Prize in Physiology or Medicine in 1983, would agree with Polyani and the chemists that "[t]hings are more marvelous than the scientific method would allow us to perceive" (Fox-Keller, 1983, 203). Her sense that something more than meets the usual scientific gaze was at work led her to the discovery of mobile genetic elements (genes that could change positions on the chromosome) and led the Swedish Academy to call her work as groundbreaking as Mendel's.

Science advances not only through its ability to reduce systems to their falsifiable essentials and test their validity, but by giving a voice to tacit ways of knowing. I am reminded of Rene Magritte's self-portrait *Clairvoyance*. The artist is gazing at an egg on the table next to him, while on the easel is emerging a bird in mature plumage. Contemplative practices can tune a scientist's ear to sources of information they can't yet fully recognize, pushing research in new directions.

A Sense of Spaciousness

Our classroom practices often favor the fast and furious over the attentive and reflective, and this agitation frequently carries over to the research lab. Can we make this grant deadline? How many hours did you put in this week in the lab? Will we be scooped by someone who worked faster?

But are fast-paced, high-pressure environments necessary for scientific progress? In a case study of the discovery of high-temperature superconductors, physicist and historian of science Gerald Holton (1996, 364) suggests the opposite: "Scientific change depends on an unforced pace of work." Seen from this perspective, science is a contemplative practice. There is no technique that guarantees enlightenment, only structures that increase the probability of discovery. Contemplative practices foster a particular patience with the world, encouraging a deliberate, unforced (though not necessarily slow) pace; imagine the swift ripple of the melismata in a chant. Spaciousness, internal and external, has value to the contemplative, as does thoughtfulness about what the work is and how it will proceed.

Contemplative traditions have something more to offer to scientists than a pacing of research work, particularly in the ways in which they create boundaries and foster a realistic balance between work and leisure. In this measured century, we can show that there is a nonlinear return on work hours. You don't get twice as much done if you work a 16-hour day as opposed to an 8-hour day, or even 50% more done in a 12-hour day (Robinson, 2012). Most monastic rules insist on daily and weekly times of recreation. Benedictine communities set aside time near the end of the day for activities that rest the mind. The cloistered Carthusian monks take a weekly long walk through the local mountains. Trappists build their monasteries on the plains, to emphasize the spaciousness of their life.

Developing a Nonjudgmental Stance

On one level, it is obvious that scientists need to be able to reserve judgment, to hold an open mind: an ability to see what is real, not what they hope is real, with respect to results and conclusions. The day-to-day doing of science also requires a decided clearness of mind and focus. Of course, many of us, from our own experience of practice in and out of the laboratory, know that we cannot achieve this; instead, there is an internal and external racket that distracts us from seeing what is there: "Is this significant? Will this be fundable? Is this publishable? Can I confirm this result before dinner? What is for dinner?" Robert Alter's (2007) beautifully raw and poetic translation from the Hebrew renders the famous "be still" of the 46th Psalm as "let go your grasp." Contemplative approaches offer ways for scientists to be able to clearly recognize and then let go their grasp on the distractions.

Awareness of Multiple Dimensions

In its 2012 report *Discipline-Based Education Research*, the National Research Council raises concerns about science students' ability to grapple with visual and graphical data (Singer, 2012). The advent of readily available computing and high-resolution graphic devices has increased the complexity and sophistication with which scientists display information. Color and depth add additional layers to lines and surfaces. Three-dimensional printing is poised to further increase the richness of information displays, enabling the encoding of data onto surfaces as textures, making it possible to render six-dimensional information in a single object.

Contemplative approaches can help students and researchers to not only cultivate an awareness of the multiple dimensions in which we engage the physical world, but also develop a facility with the audible, visual, and tactile representations of data we create.

The Practical

> Experiment escorts us last—
> His pungent company
> Will not allow an Axiom
> An Opportunity.
>
> —Emily Dickinson

How do these principles play out in practice, in my classroom and in my research laboratory? I limn below four different practices that I use when teaching writing, physical chemistry, and general chemistry (including the pre-med section), and with my graduate and undergraduate research students.

Focused Attention

The purpose of this practice of "listening outward" is to still the mind, diminish distractions, and bring focus to the work that follows. It fosters a sense of spaciousness and can be done quickly in an inconspicuous manner even in a crowded space. I teach it to students to use before they begin an exam in a crowded space, as well as to students who are trying to focus on a difficult task in a noisy laboratory.

Time: 30 seconds to 2 minutes

Sample instructions: If you wish, close your eyes. Begin to listen to the sounds nearest you - the student at the next desk rustling papers, the pumps chugging at the lab bench, the roar of the fume hoods. Acknowledge what you hear. Slowly extend your awareness outward, leaving behind as you do your consciousness of the nearby sounds. What do you hear just outside the room? In the hallway? Outside the building? Let your awareness of the sounds move outward from where you are, until it reaches the very edges of what you can hear (the nearby major street or highway?) and just beyond. Set aside each ring of sound and movement as you do so.

One image that people find useful is to think of all the noise and chaos in your mind and around it slowly flattening out as ripples do when they spread in a large pond. As the ripples move outward, the center stills.

When you have stretched your senses to the limit, hold your attention there for a moment, then take a breath and turn your attention to the task at hand.

Beholding Graphical Data

Nothing is worth noting that is not seen with fresh eyes.

—Matsuo Bashô

So much of science is visual, but despite the ability to produce and call up sophisticated visual information it can be difficult to see something you are not expecting or to try to guess what the instructor or author wants you to see in a given illustration. I use this exercise to frame a two-week section on the harmonic oscillator and vibrational spectroscopy in the physical chemistry course which is required for the major and typically taken in the junior year. Many of these students are beginning their research work, engaging for the first time with the breadth of the scholarly literature in chemistry, and they are often taking biochemistry simultaneously and struggling with 3-D images of proteins and graphs of complex kinetic data.

This exercise had its genesis in a series of conversations with the late Jodi Ziegler on her work with the beholding of art, particularly her class at Holy Cross in which students sit with and confront the same piece of art repeatedly over the semester (Dustin & Ziegler, 2005). It also draws on the Christian tradition of *lectio divina*, a practice of closely and meditatively reading short pericopes from sacred sources.

Time: Approximately 10 to 15 minutes.

Sample Instructions: I project on the screen a graph of the harmonic oscillator potential for a diatomic molecule for hydrogen bromide, HBr). The graph shows the quantum mechanical energy levels and the corresponding probability distributions for the first four states of the harmonic oscillator solutions. The probability distributions are scaled to that of the lowest energy state. The horizontal axis represents the displacement of the molecule from its equilibrium length in meters (molecules are small; the length of an HBr molecule is on the order of billionths of a centimeter).

I ask students to quietly spend 3 to 5 minutes looking at the image. I turn off the image, then ask them to take 1-2 minutes to sketch what they saw in their notes. I turn the image back on, then ask students to tell me what they notice about the graph. Various suggestions arise; I note them, without comment, on the board. I select one from the list, the one that has been mentioned most frequently, and proceed to develop the day's lecture from that point. Once we understand this point, I proceed to the next most commonly noticed point.

I repeat the beholding exercise at the start of each of the two 90-minute classes I will devote to this. At the end, if there are points that are critical that students have not brought to the surface, I am prepared to tell them what I see, but in general students at this level will, given time, notice everything I think they should about this graph. Note that you have to be prepared to lecture on what the students notice, not in the order you prefer!

I use several of these exercises during the semester, and students report on the end-of-term evaluations that these are among the most helpful thing I do, as helpful to them as the ability to write solid computer code (another prosaic skill this course teaches).

Lab Reflections

I ask research students to spend the last few minutes of their research time each day reflecting on the work just completed, going beyond the customary practice of detailing experiments and observations, planning where they will go next. This practice is well-grounded in many contemplative traditions, such as Ignatius of Loyola's Examen (Manney, 2011). On a pragmatic level, in my experience it measurably increases research productivity, as students can begin work quickly the next time they are in the lab. It also deepens their familiarity with their work: Polyani's (1967) "tacit knowledge."

Time: 5 to 10 minutes

Sample Instructions: Plan to stop your research work 5 to 10 minutes before you have to leave. If possible, sit at a desk away from the lab bench. Look over your notes from this period in lab, and flesh out any details you might have given short shrift to as you worked. Restate one or two things you observed or learned today. Write down what you will do the next time you walk into lab. Be specific: not "start a reaction" but "set up the Grignard addition for compound C, R=methyl, in the current series."

When I spoke about this in a workshop on writing for science students, a faculty member told me he couldn't imagine recommending such an approach; his immediate thought was that if he saw a student sitting at her desk writing he would tell her to get back to work. Upon reflection he wondered if that was not counterproductive. He reported to me some weeks later that this strategy of stealing time to contemplate their research had helped his students to be more efficient in the lab in the long run.

Periphrasticity

The truth is concrete (or particular).
—Karl Rahner, S.J.

Robert Boyle (1772), one of the first modern chemists, was a vocal champion of doing research in "the presence of an illustrious assembly," and the standard procedure for experiments conducted at the newly founded Royal Society required the signatures of the witnesses to be recorded. Bowing to the impracticality, even in the 17^{th} century, of gathering a scientific cohort for each experiment, Boyle advocated for vivid descriptions and elaborate woodcuts, rich with circumstantial details that served to create the illusion that the reader was present in the laboratory.

Scientists today often take a periphrastic approach to the creation of new vocabulary. The term *laser* arises from the acronym *light amplification by stimulated emission of radiation*. This description contains enough clues for an experienced quantum physicist to recreate the underlying equations that prompted the design of the laser. The particularity and richness of description are an aid to awareness—to see and appreciate in all its particularity "what is"—as well as providing some counterbalance to reductionism. Molecules are more than their molecular structure (Francl, 2012).

This exercise is based on a writing prompt from Natalie Goldberg's (2005) helpful book *Writing Down the Bones*. I have used it when teaching a research methods course which included substantial laboratory time as well as the writing of several long research reports; when teaching science writing; and in workshops for students and practicing scientists. The subject can be varied to suit audience and circumstances, though I have a personal preference for the whimsical. I have used durian in a workshop for students in Singapore, where the unusually scented fruit is a delicacy to some (and a smelly nuisance to others), or an extremely familiar (to chemists) molecule such as benzene.

Time: variable, typically from 5 minutes to 15 minutes

Sample Instructions: Tell me everything you know about Jell-O. Be rich, even over-the-top, in your description. Write freely, to be read only by yourself. Use adjectives with abandon; modify metaphors as needed.

In addition to expanding their awareness of their work, giving scientists permission to be poetic and lively in their descriptions of their work eventually enlivens their formal writing. I often close this exercise by sharing newspaper editor William Allen White's advice (often attributed to Mark Twain) that if you write "damn" everywhere you want to use "very," your editor will take out all the "damn"s and your prose will be perfect. Vibrant prose that has been dialed back in a formal work is more likely to retain a touch of that vividness in its final form than stiff writing that one tries to liven up after the fact.

Conclusion

Marcel Proust (2006) noted in *Remembrance of Things Past* that the real voyage of discovery consists not in seeking new landscapes but in having new eyes. My hope here is to show that a contemplative stance in the classroom and in the laboratory is not at odds with a scientific one, when seen with different eyes. The late Jesuit theologian and writer Walter Burghardt (2008) called meditation "a long, loving look at the real" and I suspect many scientists would not argue with that as a description of what they do. Nor, I imagine, would many poets. On one level I see contemplative approaches in science to be a link to humanistic methods of inquiry, an overlooked bridge between C.P. Snow's (2012) "two cultures."

Felix Bloch and Edward Purcell won the Nobel Prize in 1952 for their pioneering work on nuclear magnetic resonance (NMR), the fundamental physics behind magnetic resonance imaging (MRI). The opening to Purcell's Nobel lecture is almost poetic in its intensity and describes a loving look at his very real science:

> Professor Bloch has told you how one can detect the precession of the magnetic nuclei in a drop of water. Commonplace as such experiments have become in our laboratories, I have not yet lost a feeling of wonder, and of delight, that this delicate motion should reside in all the ordinary things around us, revealing itself only to him who looks for it. I remember, in the winter of our first experiments, just seven years ago, looking on snow with new eyes. There the snow lay around my doorstep—great heaps of protons quietly precessing in the earth's magnetic field. To see the world for a moment as something rich and strange is the private reward of many a discovery.

In her book *The Cloister Walk*, Kathleen Norris (1997) wonders how to "keep as much of the monastery in [her] as possible" as she and her husband return to their daily routine, and how she can draw on the wisdom of the Benedictine scaffold for a monastic life in her day-to-day life outside the walls. I hope that I have shown that there is practical knowledge to be gleaned from what seem like such impractical lives, and that, regardless of how one frames or defends them, such ways of being have a place in the scientific landscape.

Above all I hope that, however we approach teaching or research, we deliberately cultivate in ourselves and our students a sense of wonder, and even joy, in what we see, for most of us do science, not to dispassionately strip the universe of mystery, but for the delight of seeing the world, at least for a moment, as a rich and strange place.

> But out of such persistence arose turtles, rivers,
> mitochondria, figs—all this resinous, unretractable earth.
>
> —Jane Hirshfield, *Optimism*

References

Alter, R. (2007). *The book of Psalms: A translation with commentary.* New York: W.W. Norton.

Brooks, A. S., Hare, P. E., Kokis, J. E., Miller, G. H., Ernst, R. D., and Wendorf, F. (1990). Dating Pleistocene archeological sites by protein diagenesis in ostrich eggshell. *Science*, *248*, 60-64.

Boyle, R. (1772). The works of the Honourable Rober Boyle. London: Rivington. p. 173.

Burghardt, W. (2008). Contemplation: a long loving look at the real. In G. W. Traub (Ed.), *An Ignatian spirituality reader.* Chicago, IL: Loyola Press.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*, 255–265.

Consolmagno, G. (2008). *God's mechanics: how scientists and engineers make sense of religion*. San Francisco: Jossey-Bass.

Daniels, F., & Johnston, E. H. (1921). The thermal decomposition of gaseous nitrogen peroxide: A monomolecular reaction. *Journal of the American Chemical Society*, *43*, 53.

Dustin, C., & Ziegler, J. (2005). Practicing mortality: art, philosophy, and contemplative seeing. New York: Palgrave Macmillan.

Ehrenreich, B., & English, D. (1978). *For her own good: 150 years of the expert's advice to women.* New York: Doubleday.

Keller, Evelyn Fox. 1983. *A Feeling for the Organism: The Life and Work of Barbara McClintock*. W.H. Freeman & Company.

Francl, M. (2012). Zen and the art of molecules. *Nature Chemistry*, *4*, 142-143. doi:10.1038/nchem.1279

George, J., Bada, J., Zeh, J., Scott, L., and Brown, S. (1999). Age and growth estimates of bowhead whales (*Balaena mysticetus*) via aspartic acid racemization. *Canadian Journal of Zoology, 77*, 571-580.

Goldberg, N. (2005). *Writing down the bones: Freeing the writer within*. Boston: Shambhala.

Holton, G., Chang, H., and Jurkowitz, E. (1996). How a scientific discovery is made: A case history. *American Scientist, 84,* 364-75.

Manney, J. (2011). *A simple, life-changing prayer: Discovering the power of St. Ignatius Loyola's Examen*. Chicago: Loyola Press.

Norris, K. (1997). *The cloister walk*. New York: Riverhead Books.

Russell, I. J., Hendricson, W. D., & Herbert, R. J. (1984). Effects of lecture information density on medical student achievement. *Journal of Medical Education*, *59*, 881-889.

Polanyi, M. (1967). *The tacit dimension*, New York: Anchor Books.

Proust, M. (2006). *Remembrance of Things Past, Vol. 2*. Hertfordshire: Wordsworth Editions Ltd.

Puhl, L. (1951). *The spiritual exercises of St. Ignatius*. Chicago, IL: Loyola University Press.

Purcell, E. M. (1952). *Nobel Lecture: Research in nuclear magnetism*. Retrieved from http://www.nobelprize.org/nobel_prizes/physics/laureates/1952/purcell-lecture.html

Robinson, R. (2012, March 14). Bring back the 40-hour work week. Salon.com. Retrieved from http://www.salon.com/2012/03/14/bring_back_the_40_hour_work_week/

Singer, S. R. (2012). *Discipline-based education research: understanding and improving learning in undergraduate science and engineering.* Washington, D.C.: National Academies Press.

Snow, C. P., & Collini, S. (2012). *The two cultures*. New York: Cambridge University Press.