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Cover Page Footnote

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Faith and Reason in the Pursuit of Understanding

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Abstract

Both faith and reason must contribute in the pursuit of holistic understanding in the sciences. Just as maintaining an exclusively wave or particle view of matter would be incomplete, faith must be coupled with reason to develop scientific paradigms and even more so to challenge these. Artificially separating these two facets from evolving our comprehension leads to intellectual dishonesty. Current advances in science and technology hold great potential. The powerful impact these have on our lives and our world necessitate deep consideration beyond what is simply feasible to what is moral and just, concepts of great importance whose understanding is not developed via the scientific method. By joining faith with reason, we can hope for the promises of modern advances to be realized in the context of what is good and true.

Body and soul are not two different things, but only two different ways of perceiving the same thing.… There are only two ways to live your life. One is as though nothing is a miracle. The other is as though everything is a miracle.
—A. Einstein

Introduction

As a quantum chemist, my research involves extensive number crunching and complex (literally!) calculations. I recently had the opportunity to participate in Loyola Marymount University's 2016 President's Institute with the theme, "*Fides et ratio*: The pursuit of faith and reason in the 21st century Catholic university." Initially, I interpreted this by equating reason with science (or at least the knowledge that can be gained and the subsequent worldview that can be constructed via the scientific method) and faith as one's religious views. Over the course of the week-long institute, I came to realize that my definitions of both faith and reason were too limited. In my personal experience of instances pitting science versus religion, these are most contentious when a straw man is erected to represent the opposing side. Even though individual advocates of science or religion might see absolutely opposing worldviews, most of us incorporate a balance of faith and reason as we construct our understanding of the world and make sense of our place in it.

My area of research specialization is *ab initio* electronic structure calculations. *Ab initio* or "from the beginning" means relying solely on the equations underpinning quantum mechanical theory without invoking empirical measurements. More specifically, I employ numerical analysis techniques to solve the Schrödinger Equation for the quantum mechanical wavefunction of many-particle systems. The building blocks of nature including light (photons) as well as matter (electrons, etc.) exhibit wave-particle duality, and a given measurement typically elicits features of one or the other depending on experimental design. Albeit more challenging to understand physically, the wavefunction is much more information-rich than a discrete particle. Even though only one aspect of the duality may be evidenced by a given measurement, both are considered fully present and fundamentally inseparable. The "truth" simultaneously contains both the wave and the particle forms. Similarly, faith and reason present distinct lenses for developing understanding.

Limitations of sorting into preexisting boxes

Before the 20th century, prevailing scientific understanding treated matter as particles and light as waves. However, the debate on light was an extended and lively one with prominent figures championing both sides until James Clerk Maxwell effectively silenced this dilemma when he published his equations with light behaving as waves (the electromagnetic field). As a historical frame of reference, Maxwell's equations were introduced the same year the United States Civil War began. The mathematical elegance and predictive power of these equations seemed to settle the question on the nature of light—for a time.

More than two thousand years earlier, Aristotle was championing the view of earth, wind, air, and fire as the building blocks of nature over Democritus' even earlier atomic theory. *Metaphysics* is one of Aristotle's most famous works and a persistent branch of philosophy. According to Aristotle, substances exhibit hylomorphism, that is, they are composed of two *separate* things: "matter" and what we might consider to be Plato's "forms". He also explores *separate* spheres in the structure of the universe, where the heavenly spheres operate independently from the earthly center as well as monotheism in the form of a prime or "unmoved" mover. Although *Metaphysics* remains influential 2300 years later, such *separations* in space and substance are not included in our modern scientific understanding even as we come to embrace quantum duality.

In quantum mechanics, the term *metaphysics* may be used colloquially to reference the extra-science issues that modern physics seems to imply—where the classical concepts of causation become vague and transcend the scope of scientific discourse. Used in this way, "metaphysics" may be derogatory among scientists. Namely, in attempting to interpret quantum phenomena, one has pushed the search for meaning beyond the realm of science. Nevertheless, this metaphysics may provide fertile ground for philosophical interpretation such as discussed in *The Wave Function: Essays on the Metaphysics of Quantum Mechanics*.[1] This might raise the question as to whether there is scientific value in considering such interpretations. Perhaps at least insofar as it restrains the psychological desire to oversimplify and neatly compartmentalize answers to complex questions.

Separation—inherent or perceived?

Separate spheres of movement—*separate* substances—*separate* but equal. Reading these last words, Aristotle's *Metaphysics* may not be the first thing that comes to mind. It might recall instead the much more recent history of our nation's flailing attempts to cling to the remnants of legalized slavery. Segregation was adopted as a means of holding to the letter of the law of inclusion, all the while maintaining separation—in effect, legalizing a lie. As mentioned, this lie began unravelling with spilled blood at the same time Maxwell's equations of light were introduced in 1861.[2]

Each year in the Christian calendar, the season of Lent begins with ashes symbolizing that we come from and shall return to dust and the grief arising from our *separation* from God via sin. Jesus came to end *separation* initiated by the "Father of lies" (John 8:44, NIV) and to bring us into harmony with the source of truth and life. Jesus talks about *separation* in the Gospel of Mark (Mark 3:24, NIV) saying "If a kingdom is divided against itself, that kingdom cannot stand." Upon his death, the tearing of the temple veil *separating* the outer area from the Holy of Holies provides a vivid symbol of his perfect sacrifice ending our *separation* from God. Of course, this notion of *separation* may have little context unless one embraces a spiritual "soul" inseparable from our material and mortal composition. Hylomorphically, is the soul our true "form" in this sense? James Martin, S.J. wrote an opinion piece for the *Washington Post* during the season of Lent, a time focused on drawing closer to God. It was titled, "Jesus Had a Body. Here's Why That Matters for Lent."[3] Although it may be tempting to view Christ's sacrifice as addressing a spiritual *separation*, the focus on the bodily resurrection highlights faith in the essential importance of the material in this mystery. Matter *matters*.

I have been trying to highlight the idea of *separation* in these examples where *separate* has a false, limited subtext or required tension to maintain. I distinctly recall learning to spell the word *separate* while reading the classic novel *A Separate Peace* by John Knowles.[4] After seeing the cover of that book enough times, I finally was able to remember that the middle letter in *separate* is an "a" instead of an "e." This book follows the protagonist Gene's loss of innocence as his impulsive action spurred by perceived rivalry ultimately destroys Phineas. My personal view of science and spirituality has at times displayed the dualism of Aristotle's *Metaphysics* or what could be described as intellectual segregation or maybe just "A *Separate* Peace." These two facets acted like lanes in a lap pool, coexisting but never joining, or like quantum experiments, only revealing one side of the inherent duality in any given measure.

Early in my career, I felt lucky to be in the physical sciences and thus avoid origins debates that lurked around public discussions of the life sciences and seemed to place faith at odds with science and reason. The greatest champions of science and faith often seemed diametrically opposed. In retrospect, my conflict avoidance was putting me in jeopardy of intellectual dishonesty. I recently served as a respondent for Loyola Marymount University's 2016 Mission Day with the theme, "Finding God in All Things: Toward an Evolutionary Architecture of Life." Modern Catholic teaching sees no need for conflict between the accounts of Genesis and the tool of evolution accomplishing the good that is God's creation. Separation of faith and reason is an erroneous perception; faith and reason can work together to provide more complete understanding. Nevertheless, debate can be very necessary at times. Science progresses best only with open debate while faith must be refined by testing.

Entropy and paradigms

Scientific inquiry should proceed according to the scientific method in what is designed to be a self-correcting testing of hypotheses. Philosophers of science Thomas Kuhn and Michael Polanyi provide my favorite description of how science progresses. In Kuhn's *The Structure of Scientific Revolutions*, he describes *normal science,* where science proceeds with small incremental discoveries within a given framework, and only very rarely is punctuated by *extraordinary science* requiring a completely new paradigm.[5] One hundred years ago, physics underwent just such a paradigm shift.

The dawn of modern physics had an unlikely start. Max Planck was locked in a scientific debate with Ludwig Boltzmann while attempting to solve a persistent problem on the issue of black-body radiation. Both were physicists in the established field of thermodynamics; but Boltzmann felt that true understanding required statistical analysis of an enormous number of particles yielding the collective energetics observed. His insights were developed through a statistical approach to *entropy*—the most perplexing thermodynamic quantity, commonly thought of as disorder, and the basis for the Second Law of Thermodynamics (Largely this is what necessitates the flow of time itself!). Additionally, Boltzmann's approach allowed prediction of an absolute value for entropy (an unambiguous zero) and hence the Third Law of Thermodynamics.[6] At first, Planck was not convinced and set out to prove Boltzmann wrong; instead he ended up laying the foundation for quantum mechanics and improving Boltzmann's description. Their open scientific debate allowed a fundamental understanding of entropy or disorder to develop a revolutionary new order to our working theory of matter and eventually even space-time through Einstein's introduction of relativity.

Figure 1 displays images of Ludwig Boltzmann's tomb in Vienna. The top of the stone features the statistical equation for entropy with W representing the number of "ways" to arrange a system and providing a true zero for entropy when there is only a single way to order a system, i.e., W=1. Assuming he approved this, I always wondered if Boltzmann had a morbid sense of humor—putting the equation for entropy on his tombstone while his grave held the decay that accompanies death! Perhaps this interpretation did not occur to him though, and he simply wished to be permanently connected with his greatest contribution to science.

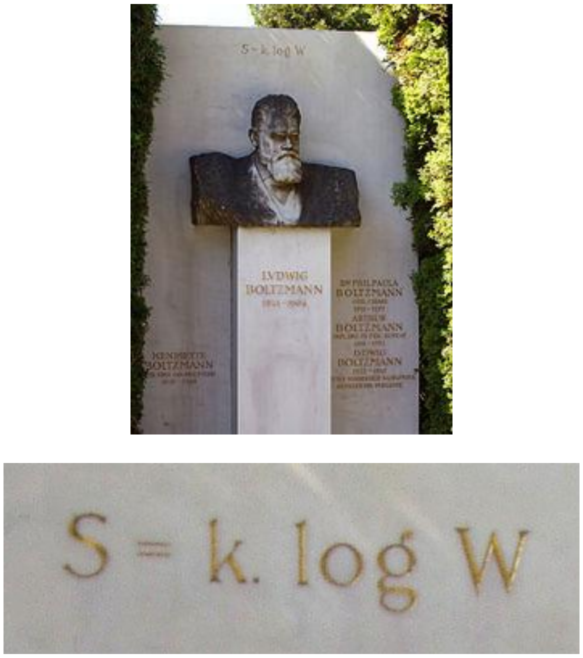

Figure 1. Ludwig Boltzmann's tomb featuring his statistical equation of entropy at the top of the tombstone (enlarged for clarity in the second frame)

Ethical implications of scientific progress and shifting paradigms

"Death brings disorder, but *Life opposes entropy*"—I developed a version of this to repeat to myself to inspire patience when walking my sons to school on rainy mornings—they felt compelled to rescue each and every worm stranded on the sidewalk! It seems there is an innate desire to promote and preserve life spurred more by faith than reason. Life sciences recently experienced a paradigm shift, and the separation between the life and physical sciences is disappearing. Our current understanding of the genetic code allows unprecedented insight and predictive capacity both into future cures of disorders as well as into our past as a species and the elegant relationships of all living things. Robust debate in science is helpful so long as the debate remains open to empirical evidence, and that framework has encouraged an amazing blossoming of knowledge.

The burgeoning capabilities to "control" life realized via advances in biochemistry and genetics are fraught with questions that transcend reason. "With great power comes great responsibility"—versions of this quote have been attributed to the likes of Voltaire, members of the French Revolution, Winston Churchill, and Franklin D. Roosevelt among others. Of course, the most famous modern attribution appears in the origin story of the great physical chemist Peter Parker—better known as Spiderman! Perhaps the earliest instance is contained in Luke 12:48 (KJV), "For unto whomsoever much is given, of him shall be much required: and to whom men have committed much, of him they will ask the more."

Recent pinnacles of scientific accomplishment are linked inextricably with deep moral questions that cannot be answered using the scientific method. The promise of genetic engineering to aid in feeding an ever-growing world population is balanced with the specter of "designer" babies, the conveniences of modern life in wealthy nations with the social justice concerns of resource exploitation, pollution, and climate change. Robert Oppenheimer in his "Atomic Weapons" speech to the American Philosophical Society in January 1946 reflected:

> We have made a thing, a most terrible weapon, that has altered abruptly and profoundly the nature of the world. We have made a thing that, by all standards of the world we grew up in, is an evil thing. And by doing so, by our participation in making it possible to make these things, we have raised again the question of whether science is good for man, of whether it is good to learn about the world, to try to understand it, to try to control it, to help give the world of men increased insight, increased power. Because we are scientists, we must say an unalterable yes to these questions; it is our faith and our commitment, seldom made explicit, even more seldom challenged, that knowledge is a good thing in itself, knowledge and such power as must come with it.[7]

Whether or not we share the same confidence as Oppenheimer, the nature of scientific truth (i.e., understanding attained via the scientific method) seems to be such that it will be uncovered. It is only a question of when and by whom. Declarations of "good" join faith with reason in science. In this regard, his conclusion may be unavoidable even if our logic justifying the pursuit of science is distinct from his.

But many questions remain. Are faith and reason separable? Should one have primacy over the other? In what ways are these complementary or in opposition? What moral imperatives or restraints are connected with scientific discovery? I already highlighted a few instances historically where the prevailing scientific view was incomplete or wrong in understanding the natural world. Yet we have faith in scientific progress and see many examples of this in advancing technology! Modern physics seems unique in its predictive power and fundamental mathematical description that is verified via empirical observation but not conceptually dependent upon it as it had been prior to the 20th century. *Ab initio* knowledge seems more comprehensive than a collection of empirical facts. Doubtless, our understanding remains incomplete though.

We must have faith that our pursuit of science has meaning even while scientific inquiry might be associated more naturally with reason. There are laws and "truths" that we can discover. Aristotle's prime mover and the global rise of monotheistic religions were important historically in the progress of science. Humanity needed to shed the notion of capricious gods toying with nature to accomplish their petty ends before we could embark fully on the path of scientific discovery. In that sense, a form of faith is needed in science even beyond the question of ethics. Additionally, practitioners of science adopt a paradigm and progress mostly takes place within that worldview. An element of faith is needed to accept the prevailing view and even more faith is required when old views must be discarded. Beyond this, I would argue that the joy of scientific discovery is best experienced from a place of awe and humility—recognizing one's own triviality even while attempting to uncover the secrets of the universe.

Do we need reason to help shape and guide our faith? It seems apparent that the answer is affirmative, barring "blind faith" which would prohibit orderly progress. As mentioned earlier, one of the more contentious issues between faith and science that has inspired lawsuits in public education is the question of how the universe came into being. This may seem to be a deep question of faith that threatens a worldview regarding our uniqueness and relative import. Yet many deeply religious individuals see no dichotomy for creation to be accomplished via a natural order. Ignoring evolution would limit scientific progress aiding human health and other beneficial aspects of science. There are grave ethical implications for discounting scientific evidence when the implications conflict with our desire for action or inaction. As we typically work within a paradigm in science, so too we experience organized religious observance shaped by prevailing interpretations. This is true regardless of the provenance and preservation of sacred texts. Of course, faith might be less formal than one's religion and encompass a moral worldview accepting certain truths. Regardless, these are necessary to test with reason, with the scientific method presenting the systematic means for this in the physical world. The infamous anecdote of Aristotle assuming that man's superiority meant men had more teeth than women is a humorous example of the dangers of ignoring empirical evidence. According to Ignatius Loyola, the things in this world are presented to us "so that we can know God more easily and make a return of love more readily."[8]

Implications of faith and reason in science for our daily lives

If faith and reason are inseparable, how does this manifest practically in the classroom and in our professional and everyday lives? Loyola Marymount University's mission involves three pillars: the encouragement of learning, the education of the whole person, and the service of faith and the promotion of justice. Even in the abstract and esoteric world of physical chemistry (covering thermodynamics, kinetics, and quantum mechanics), encompassing all three pillars necessarily links faith and reason. Encouragement of learning may seem to be the main "deliverable" of a university, yet this challenges us as faculty beyond mere competence in our subjects. We must find ways to promote desire for learning in our students and ourselves by striving to stay current, creative, and engaged in our thinking and applications. Unless our classes push beyond rote learning to explore deeper meaning, we fall short in this encouragement. The wish to educate the whole person and unite faith and reason can shape our approach to learning and how this is measured. This may involve rewarding the journey as opposed to the destination in technical subjects, i.e., assigning more credit for displaying creativity and understanding in problem solving rather than simply arriving at a correct answer.

Perhaps the most obvious way in which "the service of faith and the promotion of justice" can be accomplished is through application. By that I do not mean problem sets to test one's skills in partial derivatives and multivariable integration. Instead, we must find ways to employ these somewhat complex and esoteric skills to serve humanity. This may take a variety of forms. My personal experience has attempted to realize professional meaning through choice of research questions related to alternative energy technologies and involvement in federal science policy as well as by investing in teaching the next generation of scientists and citizens. Of course, others may achieve integration of faith and reason through service learning or careers explicitly dedicated to the service of others.

Policy examples

After my graduate studies, I worked on science policy issues in the United States Senate. It will come as no surprise that this experience was contrary to my years as a full-time research scientist calculating numerical approximations to wavefunctions on national supercomputers! Several policy issues I worked on during that time encapsulate the interconnected nature of faith and reason in applied pursuit of understanding and meaning.

One of my first policy issues in the Senate related to the rise of resistant strains of human pathogens due to antibiotic (over)use. Recent incidents of hospital patients with infections unresponsive even to last-resort antibiotics have received top headlines. Although this has been a global issue for some time, the United States typically had not faced domestic instances with no drug displaying efficacy. In 2002, one policy issue related to the concern over creating resistant "superbugs" via prophylactic antibiotics used to facilitate livestock factory farming. The science or "reason" of drug resistance could be traced through genetic analysis of bacterial populations. The face and "faith" of this policy issue, however, took the form of a sweet grandmother who met with me to develop legislation to limit antibiotic overuse in agricultural animals as a way to honor the memory of her beloved grandson. He died of an infection acquired from eating meat contaminated with a resistant strain of E. coli, and she wanted to ensure his death was not in vain. She believed some good could result from her tragedy via legislation aimed at improving food safety standards. This faith drove her to meet with me persistently for months and spurred me to work with members of the Senate and their staff as well as stakeholders on both sides of this issue. Eventually, we introduced S. 1460 in the 108th Congress sponsored by Senator Kennedy and joined by Senators Snowe, Reed, and Bingaman as a result of these efforts. Many bills are introduced which never become law or even come to a vote. This may seem discouraging, yet faith in the legislative system must hope in the value of raising awareness on such issues regardless of legislative outcome.

On February 1, 2003, the Columbia Space Shuttle disintegrated upon reentry. An endeavor as complex as the space program necessarily involves thousands of scientists, engineers, technicians and administrators performing their individual roles while simultaneously relying on all others involved. Although certain redundancies and safeguards can be built into the planning, the margin for error is very slim for the mission to be successful. Grand visions require individuals to exhibit faith by relying on the specialization, expertise and accuracy of his or her colleagues even while individual efforts are founded in reason and highly technical. It is a testament to how well this typically works that accidents are rare, especially considering the active use of the shuttle program extended many years beyond its planned lifetime due to the needs of the International Space Station. Unfortunately, the shuttle loss on February 1st displayed that even well-run missions can end in tragedy.

I assisted in the Joint Hearing on Columbia Disaster and Future of NASA by the U.S. Senate Commerce Science and Transportation Committee and the House Science Committee. The major goals of this hearing were to interview

Sean O'Keefe, then Administrator of NASA, to determine the cause of the accident, the timeline of what was known when, and the steps NASA was taking to ensure the safety of future missions. Just prior to my work with the Senate, I had been involved in the High Performance Computing Modernization Program through the Department of Defense as a research scientist with projects in multi-scale modeling where quantum mechanical information was joined with larger-scale engineering simulations (finite element methods). Accordingly, I was uniquely aware of the limitations in the NASA simulations performed in the aftermath of the Columbia accident that attempted to unravel the series of events leading to the disaster. I wrote a line of questioning used in the hearing accordingly. Initially, Administrator O'Keefe's answers were dismissive of these concerns. During a brief coffee break, I was concerned that the senators would be frustrated by my prepared questions and statements since these concerns had been dismissed so quickly. To my surprise, they were already convinced that our line of questioning was correct. Although NASA's early simulations to understand the accident were accurate within their limited construct, they did not capture the physics essential for assigning disastrous consequences to the foam pieces that broke from the fuel tanks upon takeoff. A combination of detailed understanding of the science—what it includes as well as what it neglects in the case of simulations—and faith in the results and work of others is necessary to progress in large-scale scientific endeavors. Grand missions will fail if faith and reason do not work hand in hand.

The second Iraq war began during my time working in the Senate. The prevailing view on both sides of the political aisle in the Senate was that action was necessary. This conclusion was grounded in reason based on multiple layers of information and, what later appeared, misinformation. The most noteworthy memory for me the time leading up to the active engagement is hearing Secretary of State Colin Powell discuss the challenge for our country entering this war: that it would be much more drawn out, complicated, and draining than people were prepared for at that time. Faith in a quick and clean resolution was ill-founded. The now-famous "Mission Accomplished" landing of President George W. Bush on the USS *Abraham Lincoln* on May 1, 2003 initially seemed to refute Secretary Powell's fears. The subsequent guerrilla warfare activities and mass casualties on both sides ultimately proved his fears prescient.

Analyzing scientific choices

"Just because something can be done doesn't mean it should." In a simple way, I believe that this statement captures the mutually dependent nature of faith and reason in ethical application of science and technology. During my time working in federal science policy, this sentiment was expressed for issues such as embryonic stem cell research and national healthcare costs with a disproportionate percentage being spent on heroic measures in the last weeks of life. On a more personal level, I have heard versions of this statement twice in the past year.

As a chemistry professor, we teach our students how to make molecules and how they react. There is a significant amount of factual content to impart that is seemingly devoid of ethical implications. It is just the way the physical world "works." After years of interest and some individual involvement in green chemistry, I was very happy to bring together my department to sign the Green Chemistry Commitment this past year.[9] Senator Snowe, with whom I worked during my time in the Senate, introduced the Green Chemistry Research and Development Act initially in 2008. "Just because something can be done doesn't mean it should," could be said to form the underlying motivation for the field of Green Chemistry. "Benign by design" is a more succinct slogan for the field of Green Chemistry.[10] Just because chemists can make many specialty and fine chemicals using certain tried and true "recipes" (synthetic pathways) does not mean that it is a successful or sufficient answer if the process entails making a thousand-fold more byproducts toxic to human health and the environment as part of the synthesis. Creating the target chemical is only part of the puzzle, and our job as scientists must necessarily involve the whole picture.

As a mother, I had the misfortune of hearing these same words "Just because something can be done doesn't mean it should" from a neonatologist discussing medical options as my third son was about to be born prematurely. Facing the death of a loved one rather than abstract figures of disproportionate expenditures in end-of-life policy debates provides a poignant illustration of the inadequacies of reason alone in analyzing scientific questions. The contribution of faith and reason to understanding loss and grief is difficult to balance. Restraint is easier in the hypothetical than in reality.

When faced with scientific choices but no real solutions, we hope to make the right decision even while we are unable to assign the "correct" answer. Hope encompasses a powerful aspect of our humanity not nurtured by the "dispassionate observer" inherent in the scientific method. The nature of hope has been explored for millennia. Romans 5:3-4 (NIV) states "Not only so, but we also glory in our sufferings, because we know that suffering produces perseverance; perseverance, character; and character, hope." And "hope" is not a new concept here, as we are reminded in Hebrews 11:1 (KJV) that it is actually a manifestation of faith, "Now faith is the substance of things hoped for, the evidence of things not seen."

Conclusion

I said "Just because something can be done doesn't mean it should" had impacted me twice in the last year. In fact, it arises more often, typically as a reminder by students in the last five minutes of class when I suggest delving into a quantum derivation that might run overtime! As we engage in research and benefit from scientific progress, we have the privilege of standing on the shoulders of giants. Yet we must not allow our respect for their accomplishments to close our minds to new paradigms and understanding that can only be realized fully when faith is united with reason. Albert Einstein may be the greatest individual contributor to science. Always a critic of rote learning, he noted, "A society's competitive advantage will come not from how well its schools teach the multiplication and periodic tables, but from how well they stimulate imagination and creativity."[11] We each may define faith and reason in slightly different terms based on our understanding, experience, and field of study, yet education of the whole person must join these as we pursue understanding of truth and the sublime.

Notes

[1] Alyssa Ney and David Z. Albert, eds., *The Wavefunction: Essays on the Metaphysics of Quantum Mechanics* (Oxford: Oxford University Press, 2013).

[2] James Clerk Maxwell, "On Physical Lines of Force," *Philosophical Magazine Series 4* 21 (1861): 161, 281, and 338; and 23 (1862): 12 and 85.

[3] James Martin, S.J., "Jesus Had a Body. Here's Why That Matters for Lent," *Washington Post*, February 10, 2016, https://www.washingtonpost.com/news/acts-of-faith/wp/2016/02/10/jesus-had-a-body-heres-why-that-matters-for-lent/.

[4] John Knowles, *A Separate Peace* (London: Secker and Warburg, 1959).

[5] Thomas S. Kuhn. *The Structure of Scientific Revolutions.* (Chicago: University of Chicago Press, 1962).

[6] The First Law of Thermodynamics states that energy cannot be created or destroyed but can be transferred from one form to another. The Second Law states that the entropy of the universe is increasing. The Third Law states that the entropy of a perfectly crystalline substance with no thermal energy is zero.

[7] J. Robert Oppenheimer, address to the American Philosophical Society, Philadelphia, PA, November 16, 1945.

[8] Kevin O'Brien, *The Ignatian Adventure: Experiencing the Spiritual Exercises of St. Ignatius in Daily Life* (Chicago: Loyola Press, 2011) p. 69.

[9] "Higher Ed Green Chemistry Commitment," Beyond Benign, accessed July 31, 2017, http://www.beyondbenign.org/he-green-chemistry-commitment/

[10] Paul T. Anastas and Carol A. Farris, *Benign by Design: Alternative Synthetic Design for Pollution Prevention* (Washington DC: American Chemical Society, 1994).

[11] Walter Isaacson, *Einstein: His Life and Universe* (New York: Simon & Schuster, 2017) p. 6-7.