The Divide Between Humanities and Science

Why it Matters and How it can be Repaired

Edited by

Richard C. Brusca

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Cover art, *Undercurrent* (detail), 2017, by Daniel Zeller. Ink and acrylic on paper, 18 x 23 inches

Preface

You've most likely not seen a book quite like this before. It describes consilience between science and the humanities by revealing a secret: while university scholars wring their hands trying to imagine how consilience might be achieved, it turns out a lot of creative people have been doing it all along. It's simply what they do, how they think and see the world, where they live in their minds and hearts. The essays in this volume are testimony that E. O. Wilson's dream of consilience has been manifest all along; we just had to look in the right places for it.

The 16 essays in this volume (by 21 contributors) come from scientists, educators, artists of all stripes, businesspeople, and deep thinkers. They represent a wide breadth of views by people in different professions who appreciate the wisdom and human benefit to be gained by integrating science and humanities.

It seemed only fitting to open this book with a poem by Sam Illingworth, written specifically for this volume. *Threads of Knowing* explores the intersection of sciences and the humanities and how, in both, we engage in a shared search for understanding. Professor Illingworth's poem reflects the idea that knowledge, whether scientific or artistic, is a continuous weaving of ideas across boundaries, both seen and unseen. Sam's words remind us of the importance of focusing on the union of seeking and knowing.

As editor of the volume, I decided to take a 30,000-foot-view of why consilience between science and humanities is important, with examples of how this is being accomplished by some of our best thinkers. Thus, my opening chapter ("The Integration of Humanities and Science").

The first section of this book, "Bridging Humanities and Science in (and Outside) the Classroom," includes essays by nine deeply invested higher education professionals, beginning with Sylvia Torti, a brave and visionary education leader who provides concrete examples of how higher education can interweave these two great human endeavors in creative ways. Sylvia, a trained biologist, essayist, and fiction writer, and President of College of the Atlantic in Maine, offers up a firebrand notion of how higher education needs to change to meet our rapidly changing world—*all education must be ecological in nature* she argues. Sylvia provides ideas and hypotheses that make good sense, but we'll see how the conservative academe reacts. Students at her college will be trained equally in both science and humanities following her creative recipe for success in this Brave New World we are facing.

W. F. Gilly describes the process he and his Steinbeck-scholar wife Susan Shillinglaw went through developing courses that sought to bring science and humanities and philosophy together through the lens of John Steinbeck's legendary *Log from the Sea of Cortez*. This important, detailed, and extraordinarily useful accounting offers a blueprint for others who may wish to develop similar courses.

Kelly Presutti, Verity Platt, Johannes Lehman are three professors at Cornell University, from different departments that one would not expect to be collaborating on a course. But they clearly believe that bringing science and the humanities (in this case, art, theater, and dance) together can generate a powerful teaching milieu. Partnering with a colleague from Cornell's Performance and Media Studies, students (mostly STEM) react personally to the realities of climate change, write new narratives about environmental change, and grow wiser through creativity, connection, and personal transformations they experience during the semester.

Shelly L. Brown-Jeffy, Nadja B. Cech, and Omar H. Ali (of the University of North Carolina at Greensboro) describe their courses that combines ecology, history, and urban spaces through traditional and non-traditional activities that include game-playing, wandering through art museums and big-box stores, and exploring a forest ecosystem. A sociologist, a chemist, and a historian take their students out of the classroom and into the real world, empowering them to play an active role in their own learning and development. In doing so, the students become better learners, are more open to asking questions, and discover how their curiosity grows. Their experiences even led to a pop-up exhibit in downtown Greensboro that displayed the students' writing, photographs, art, and recordings. Fieldwork, it seems, may truly be one of the most powerful tools educators have.

Vera Meyer the scientist (aka V. meer the artist) believes that collaboration among scientists and artists can refill C. P. Snow's vacuum with life, metaphorically and literally—in her case, with fungi! Fungi are curious organisms to everyone, they take students out of the classroom and into the field, they are beautiful and morbid, and they are full of intriguing mysteries awaiting investigation.

The second section of this book, "Integrating Art and Science," begins with an essay by Josie Iselin, an artist and instructor in San Francisco State University's School of Design, who describes her art-science campaign to generate interest, knowledge, and conservation for the spectacular giant Pacific bull kelp, *Nereocystis leutkeana*. Josie's passion for storytelling and art raises awareness of natural history and important conservation issues and is well known to residents of the Pacific Coast of North America.

Kysa Johnson's engaging essay describes her journey as an artist (and more) and how she became fascinated by patterns in nature that are too small, or too big, to be seen with the naked eye. Kysa's work gives

life to the unseen or obscure designs of nature. Her large installations have won praise and many awards. Like Daniel Zeller, Kysa discovers and renders the meaningful threads of connection between the unseen, but real, and the everyday world in which we live. Both strive to bring the hidden patterns of the cosmos into the human visual field. Although both are visual artists—Johnson's work captures the actual patterns she discovers in nature while Zeller's work is more abstract—but the powerful similarities in their work speak to some universal, natural truth that lies just beyond our grasp.

Environmental artist and writer Andrea Polli uses highly inventive approaches to raise public awareness of environmental issues. Her public artworks have been installed at over two-dozen locations, including a wind-powered light work covering the Rachel Carson bridge in Pittsburg and building-scale works across Europe and the U.S. Her contributed essay here describes a unique venture that combines weather science, art, and public exhibition in thoroughly creative ways that educate both students and the general public about climate science.

Daniel Zeller was born in California but as art became his passion he migrated across the country to New York, where he now lives. His work is utterly unique, and even when generated in two dimensions it has a three-dimensional (or four-dimensional) quality (see this book's cover image). It is highly organic and speaks to the complex and unbreakable connections that bind together everything in the natural world. He has exhibited internationally for many years and his spectacular work can be found in the collections of MoMA and the Whitney Museum in New York, the Museum of Contemporary Art in Los Angeles, NASA, the National Gallery in Washington D.C., and many other fine museums and galleries.

In the third section, "Thoughts on Integrating Science and the Humanities," six deep-thinking individuals offer up their ideas about the business of consilience. Chris Enke dives deep into the nature of scientific knowledge, and how science differs from philosophy. Both, he concludes, are ways in which nature can be expressed and understood by humankind. And both are uniquely human endeavors. Chris notes that a scientific theory has two parts: one part is the statement of the "law" in the form of an equation or logical declaration—a simple expression of a pattern in nature we observe, but providing no rationalization for that behavior. The second part is the explanation we devise for why nature acts that way. The law is the "what" and the explanation is the "why." He also notes that only *people* do science, and they have breakthrough ideas because of their creativity and imagination which are distinctly human traits. He further argues that if we want to repair the divide between science and humanities, science journalists (and the lay public in general) need to understand the boundaries of science, what a scientific hypothesis actually is, and the seeming paradox of science and philosophy.

Ecologist Tom Fleischner, founding director of The Natural History Institute, which embodies the essence of consilience between science and the humanities, writes a reflection on the importance of natural history. He considers how, in the past, the humanities and sciences were not relegated to entirely different silos on college campuses as they are today. Tom argues that the greatest leaps in societal science have come from those moments in history when science and the humanities are in sync.

The extraordinary writer Mary Ellen Hannibal writes lyrically of the novelist, poet, and lepidopterist Vladimir Nabokov. His escape from Russia, tumultuous times in Europe, destiny awaiting him in America. When the Nabokov family had to flee their natal St. Petersburg,

Vladimir found himself a man without a country, traveling across Europe, his suitcases filled with books and butterflies. Despite his outward claims of keeping his science and his art separate, it was never really so. Butterflies and literary fiction, it seems, were indelibly intertwined, like a coiled fiber in his being. Ecologist Lisa Harris is also a photographer, essayist, and short-story writer. Lisa's essay for this book draws inspiration from her garden, which she discovers is an excellent metaphor for finding consilience between humanities and science.

Gary Nabhan, in his very personal essay, confesses that, despite his love of humanities and the natural sciences, he's been trapped in a no-man's-land, an ecotone between the two. A place he calls the *radical center*. A place that suits him well and has certainly led to a lifetime of impressive creativity—Gary's been awarded more "creativity prizes" than one can tally, including the MacArthur "Genius" Grant. This place of creative tension between traditional disciplinary silos seems to be where holism is fostered. A place most of the contributors to this volume understand. John Gregg's thoughtful essay reflects on universal patterns in nature, from the microscopic to the stellar, expressing in words what Kysa Johnson's work expresses in art. From neural patterns in the brain, to Fibonacci sequences in nature, to dancing atoms and spiraling galaxies, John informs us: "Zoom in or zoom out, it doesn't matter—the same truths are everywhere."

I want to thank Howard Browman and Paul Dayton, who encouraged me to express my thoughts on changes I've seen in science education, research, and university culture over the past sixty years (Brusca 2024, ICES Journal of Marine Science). That little essay prompted speaking and writing invitations and led to conversations with many other professionals with shared sentiments … and ultimately to this book.

List of Contributors

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Kelly Presutti. Department of History of Art and Visual Studies, Cornell University.

Sylvia Torti. President, College of the Atlantic, Maine.

Daniel Zeller. Independent artist since 1994.

Threads of Knowing

Sam Illingworth

Between sky-rivers
and the root-shifted earth,
the question drifts –
not of borders, but crossings.
Where iron-lore is etched,
fingers seek the weave.
Each atom a sky-shard,
each tale carved
from dust's own edge.
In the warp of tides and voices,
we begin to trace the unseen:
how the mind-flare echoes
across the folds of time,
how sea-keepers stir
ancient fires beneath
the water's skin.
Here, where paths
of thought entwine
a mark begins –
to fuse
the stone-weighted word
with the ember-light
of knowing.
And in this place,
under the drift
of wandering worlds
we find the reach to ask
not only how we search,
but why we seek to know.

Introduction

Richard C. Brusca

The unique genetic, physical, and social attributes of human beings that distinguish them from all other animals are fairly well known, even if not fully understood. Among these are: a large rounded braincase and enlarged, highly folded cerebral cortex, enabling high intelligence, cognition, ideation, and capacity for abstract thought, conceptualization, and reasoning; complex and evolving languages[1]; introspection and moral sensibilities; elaborate story telling; highly developed agriculture and industry; and the complex use of tools (most notably mathematics, arguably the most powerful of all human tools). The most profound expression of this humanness is our desire and ability to create. The three primary ways we create are through

[1] Language is distinct from communication. A number of vertebrates have good communication. Hyraxes, for example, use complex calls for mate attraction, and wolves, cetaceans, parrots, gibbons, and chimps use calls to mediate complex social interactions. The closest thing to a non-human language may be the "songs" of humpback whales. Just as human vocalizations are structured by a hierarchy of phonemes, words, phrases, sentences, and narratives, so too are the songs of humpback whales. Sung only by males, the songs travel through the ocean for miles. The songs are also culturally transmitted. In the southwestern Pacific, a totally new song emerges every few years that is adopted across the sea to the eastern Pacific. But only humans have a language-brain processing capacity to grammatically combine long strings of words, symbolic representations, and multiple concepts into an essentially infinite variety of meanings and ideas. Only human language is so deeply representational that we understand, and our language denotes, how one thing can be another thing. Human language allows not only for information sharing, but the discussion of complex topics, the planning of future goals, and reflection upon the past. Interestingly, the precise time when humans first began to talk to each other and what enabled them to do so are still not known.

science, engineering, and the humanities. Creativity—developing original ideas and concepts—emerges from our high level of thought, capacity for abstraction, and our deep sense of time, especially our ability to imagine future time. Humans are also the only animal species on the planet that create complex music, theater, literature, poetry, and mathematical concepts. Uniquely, we also have desires and set goals—an indicator of our ability to deeply conceptualize expectations.

The brilliant literary novelist Cormac McCarthy, in what may be his only nonfiction essay, reflected deeply on these matters in *The Kekulé Problem: Where Did Language Come From?* (2017). The essay begins by questioning the nature of the unconscious mind, noting that unconsciousness must be a far older trait than human language; at least as old as the origin of the primate lineage, and likely older (we've all seen our dogs dreaming—presumably their unconsciousness at work!). The essay's title comes from the famous story of Friedrich August Kekulé's discovery of the nature of the benzene molecule, said to have come to him in a dream; that is, from his unconscious. His dream was of a snake coiled in a hoop with its tail in its mouth, and when he awoke it immediately dawned on him that the form of the benzene molecule was a ring. The puzzle to McCarthy was, if Kekulé's unconscious knew the answer to the question that he had struggled with for so long, why hadn't it simply told him in words? Why rely on ancient Greek uroboros symbology? Why indeed does the unconscious speak to us in symbols, images, and metaphors, and not in our manifestly beautiful language. McCarthy's answer was that the unconscious is an ancient trait and the actual process of thinking is largely an unconscious affair (something Einstein also alluded to). Language, a far more recently derived trait, can be used only to sum

up what the unconscious (thinking) has arrived at. But thinking itself is not a language-based affair.[2]

The humanities are often thought of as the artistic aspect of creativity—art, music, literature, dance, theater, etc. But, in the broader sense the humanities also include languages and communication, history, philosophy, ethics, cultural studies, religions, and our abiding desire to understand the world and the universe. In short, studies of the humanities are, as the name implies, studies of humanness. Evolutionary psychologist Steven Pinker, one of today's brightest lights and most creative thinkers in psychology, linguistics, and the human condition, stated, "Our system of law, government, our economy, our assumptions about education, childrearing, and the relation between the sexes all have a rationale that was first worked out by thinkers in what we now call the humanities. Humanities are touchstones for our private and public discourse" (Pinker 2012).

This idea of humanness being defined by thought and creativity has been expressed by many writers. Even the influential modernist Virginia Woolf [1882-1941] touched on it when she wrote (in *Mrs. Dalloway*): "The compensation of growing old is that the passions remain as strong as ever, but one has gained—at last!—the power

[2] There are sporadic research papers that hint of invertebrate species having consciousness, e.g., honeybees becoming "pessimistic" after a "stressful" experience, cuttlefish remembering the past and planning for the future. However, it's hard to evaluate these kinds of studies because the nature of consciousness itself is still unclear. There are at least 22 theories of consciousness (A. K. Seth & T. Bayne, 2022, Nat. Rev. Neurosci. 23, 439), and there is general agreement that they all lack strong resolution. For nonhuman primates, such as chimpanzees, there is a high level of confidence that consciousness is present. But for the other vertebrates and some invertebrates, the best we might be able to claim is that there is a realistic possibility that consciousness is present.

which adds the supreme flavour to existence—the power of taking hold of experience, of turning it around, slowly, in the light." Woolf refers to the human trait of deep reflection across time, a process about which we have little understanding. Like reflection, we also know very little about creativity itself. Where does it come from and how it is generated? The question of what compels an artist to seek new ways to interpret humanity or nature remains one of our greatest mysteries. Woolf believed that the wellspring of creativity lies in the qualitative difference between experiences that produce anguish and those that instill gratification. But surely there could be as many sources of creativity as there are thinking people on the planet. A critical source of creativity must be the ability to recognize associations between very different sorts of knowledge or evidence—a process often galvanized through "mind wandering." Chance also plays a role in creativity. Think of Louis Daguerre's discovery of photography, Wilhelm Röntgen's discovery of x-rays, or Alexander Fleming's discovery of antibiotics (Lehmann and Gaskins 2019). But none of these chance events would have led to new, transformative discoveries had not the persons involved been deeply curious (and persistent). Thus, curiosity must also be a prerequisite for creativity. Yet most scientific experiments today are designed to reduce chance to the lowest probability, and unexpected results can lead to simply repeating the experiment. Brusca (2024), speaking of biology, notes that, "the combination of field experiences and good books can stoke fires of creativity in a learner." Kharkhurin (2015) argues that the ultimate source of creativity is transcendent attributes that lie outside the individual, and for that reason our current approaches to understanding creativity fall short. We fail to understand this phenomenon, Kharkhurin discouragingly argues, because it is possible that the source of creativity lies beyond human cognition.

The stark contrast in how great artists find their creative inspiration can be illustrated by two of the great Germanic masters, Wolfgang Amadeus Mozart [1756-1791] and Friedrich Nietzsche [1883-1885]. Mozart wrote, "When I am, as it were, completely myself, entirely alone, and of good cheer—say, travelling in a carriage, or walking after a good meal, or during the night when I cannot sleep; it is on such occasions that my ideas flow best and most abundantly" (Ghiselin 1952). Nietzsche, in his last book, *Ecce Homo: How One Becomes What One Is* (written in 1888, published posthumously in 1908), described the creative process that led to writing his great four-volume philosophical fiction *Also sprach Zarathustra* (1883-1892). At the time, Nietzsche was living on the coast not far from Genoa. He was in ill health and it was an unusually cold and rainy winter. His house was so close to the shore that the noise of the rough seas rendered sleep impossible for him. He was, at times, quite miserable. In *Ecce Homo* he wrote of this period (Ghiselin 1952): "These circumstances were the very reverse of favorable; and yet, despite them, and as if in proof of my theory that everything decisive arises as the result of opposition ['What doesn't kill us makes us stronger'], it was during this very winter and amid these unfavorable circumstances that my *Zarathustra* was born. In the morning I used to start out in a southerly direction on the glorious road to Zoagli. In the afternoon, whenever my health permitted, I would walk around the whole bay from Santa Margherita to beyond Porto Fino. It was on these two roads that all *Zarathustra*, and particularly Zarathustra himself as a type, came to me—perhaps I should rather say—invaded me." As if an augur, Nietzsche wrote: "Perhaps the whole of Zarathustra may be classified as music … a renaissance in me of the art of hearing"—foreshadowing Strauss's 1896 tone poem (*Also sprach Zarathustra*/*Thus Spoke Zarathustra*) that would be inspired by his novel.

That Mozart composed his masterpieces from a place of joy is evident in the ebullient nature of his work. And that Nietzsche's story of Zarathustra came from a darker place is conspicuous in its abstruse nature and shadowy overtones. Zarathustra, more commonly called Zoroaster in the West, was a wandering philosopher who spoke to such weighty matters as the struggle between good and evil, the death of God, the will to power, and eternal recurrence (a philosophical concept that time repeats itself in an infinite loop, and that exactly the same events will continue to occur in exactly the same way, over and over again, for eternity). The character Zarathustra was one of the early models for many similar, but more light-hearted books that followed (e.g., Thomas Mann's *The Magic Mountain* [1924], Hermann Hesse's *Siddhartha* [1922], Khalil Gibran's *The Prophet* [1923]). Nietzsche's books have been described as "nihilistic destruction combined with a life of increasing isolation." Yet both Mozart and Nietzsche stand as pinnacles of creativity in their accomplishments.

It is ironic that creativity is a fundamental aspect of humanness and yet is so poorly understood, hard to pin down, and difficult to untangle. A review of the field suggests there is little agreement on what the sources of creativity might be (DiLiello and Houghton 2006). Researchers do not even agree on a single definition of creativity. In fact, Whitehead (1978) claims the word "creativity" only appeared about one hundred years ago. Kharkhurin (2015), noting that creativity remains a poorly studied field in general, concludes it has reached an "epistemological cul-de-sac."

Humanities courses help teach students, including STEM (science, technology, engineering, and math) students, how to think creatively—and to reason and analyze complex situations. The core concepts of the humanities offer practical skills that are crucial in professional settings, such as critical thinking, cross-cultural

understanding, good writing, and clear communication. Studying the humanities, students have the opportunity to get to know themselves and others better. Through studying language, behavior, the arts, and history, students become more well-rounded individuals, can connect with and understand others better, and can embrace a larger contextual view of the world. Understanding the humanities helps us approach and analyze imperfect, subjective, and labyrinthine information. It steers us away from xenophobia, and toward understanding and empathy. It broadens our minds in ways that are healthy for both individuals and society.

Institutions of higher education have long advocated the benefits of a multidisciplinary approach in pedagogy. Colleges/schools of "arts and science," or colleges/schools of "letters and science," used to be common in higher education. In fact, *most* universities and colleges (hereafter, just "universities") once grouped their academic programs in this way. However, over the past few decades this approach has been greatly reduced, giving way to separate schools of arts and sciences. Today, Wikipedia lists only 79 such programs in U.S. higher education institutions (out of about 4,000 degree-granting postsecondary institutions in the U.S.). It's not clear how well humanities and science were ever *literally* integrated in American schools of arts and sciences, but there are a few institutions that today try to blend them in useful and creative ways (see examples below). Overall, actually integrating humanities and science in single courses seems to have always been rare. More typically students select a discipline, take most of their courses in that discipline, and then take a few courses from other disciplines. Scholars have pointed out that this type of multidisciplinary approach is flawed (Carrell et al. 2020). Getting exposure to a few topics outside their discipline does not teach them how to connect the dots, draw conclusions, and determine why a class or discipline outside their focus area is relevant to their

education goals. STEM students often remark, when taking liberal arts courses, that the only reason they are taking the class is because they "have to take it to graduate." This attitude speaks to the great divide between humanities and science, and it speaks to the desirability of HDSTEM (humanities-driven STEM) pedagogy.

Numerous scientists and teachers have written about the importance of integrating the humanities into STEM education—sometimes called STEAM (science, technology, engineering, art, and math) or HDSTEM—and merging humanities back into science in general. In particular, see Carrell et al. (2020) who argue that humanities should be at the forefront as the impetus and lens for contextualizing STEM research and discovery. Humanistic STEM blends the study of science with interest in and concern for human affairs, welfare, values, ethics, and culture. The idea is to produce well-educated science students who also have a solid appreciation of the humanities, and vice-versa. Slingerland (2008) argued that the humanities are at an impasse, and in order for them to progress they must take seriously contributions from the natural sciences.

A few books have appeared over the past 25 years that address the issue of consilience between science and humanities, beginning with Wilson's (1999), and these are intellectually satisfying reading. However, they have been written in an academic style that is most easily digested by academic scholars, and none of them provide descriptions of how consilience is actually being achieved today. They mostly avoid the pragmatic, and instead take a hypothetical or philosophical approach that emphasizes research programs (e.g., Bateson 2002, Slingerland 2008, Slingerland and Collard 2012, Varela et al. 2017). While both theory and pragmatism are needed to grapple with the issues, the latter is more practical for educators, as well as for humanists striving to see better ways to connect their work to the

sciences. To change the current paradigm of "two cultures" will require we begin at the K-12 level. By the time most students graduate from college, the separation is manifest.

Slingerland and Collard (2012) is an important scholarly volume with contributions from nearly 40 professionals, mostly higher-education professors. While being up to date and informative, it is written primarily for university researchers, not for an audience of teachers or practitioners. One of the most important takeaway messages in the Slingerland and Collard volume is that finding consilience between science and humanities research must involve more than just interdisciplinarity—it must be the development of a new, shared framework for these two great human endeavors. This is certainly true with regard to scholarly research projects, where research plans need to be developed by both sides. However, consilience is already being practiced in the world of teaching (both K-12 and university) as well as through practical application. A good example is the work of Sam Illingworth, who uses poetry and games to engender meaningful dialogue between scientist and non-scientist, and to offer scientists a humanist view of their subjects through insightful poetry. Sam is also founder of the peer-reviewed journal *Consilience*.

A number of institutions are now working to narrow the gap between science and the humanities, including MIT's Center for Advanced Visual Studies (https://act.mit.edu/event/cavs-55/) and Experiments in Art and Technology, a collaboration begun by scientists at Bell Telephone Labs and New York artists (https://en.wikipedia.org/wiki/Experiments_in_Art_and_Technology). Even CERN (the European Organization for Nuclear Research, home of the Large Hadron Collider) invites artists to spend time at the institution, facilitating collaborations with scientists to understand and visualize/represent

the structure of the cosmos. Art has the capacity to make complex science visible in society.

There are many examples in this book of what consilience between humanities and science can look like, but here is a favorite theme of mine. Imagine if students in a university ecology course took a field trip to obtain soil samples from several very different terrestrial habitats and spent a week or two analyzing and comparing the soil strata and types, and the biological features associated with each. They gain a sense of place collecting the samples and, in addition, having been told at the beginning of the course to read Steinbeck's *Grapes of Wrath*, they are then tasked to write an essay on the nature of soil, how soils can become degraded by bad agricultural practices, how those processes led to the Dust Bowl era, which in turn resulted in massive migration of farmers from the Midwest to California, and the socioeconomic forces that then changed their lives and impacted society.

Or imagine a biology course in which students study invertebrates. They take a field trip to the seashore to study tidepools (or to a lake shore, or river shore) where they estimate biological species diversity of the invertebrates in some quantitative fashion. They gain a sense of place but, in addition, having been assigned Steinbeck's *The Log from the Sea of Cortez* to read, as they analyze their data they form discussion groups that talk about the key philosophical passages in the book that reflect on the nature of biodiversity and people's different views on it (and they are asked to explain what Steinbeck meant by his admonishment: "It is advisable to look from the tidepool to the stars and then back to the tidepool again").

And, of course, there is no better way to expand young people's minds than travel abroad. Imagine if every university required their science and humanities majors to spend a semester abroad. As educators, we

should strive to create in our students a sense of wonder—in both the noun and verb spirit of the term. In the individual contributions to this book, you will see many examples of what a merging of humanities and science can aspire to be.

In fact, in recent years there has been a proliferation of art-science collaborations, some by scientists who have come to understand how the arts can enhance their work, some by artists who are also scientists, and some by artists who have learned the science through study of their subject matter on their own. A number of these are described in this book. The National Endowment for the Arts recently published an excellent issue (*A Kind of Beauty*) on the creativity that comes from cooperation between the arts and sciences (https://www.arts.gov/stories/magazine/2013/3/kind-beauty). Based on a 2010 joint workshop between the Arts Endowment and the National Science Foundation, the two agencies are now actively encouraging grant applicants to consider pursuing art+science projects.

A wonderfully detailed 2018 U.S. National Academies report notes the growing tension in universities between a liberal education and escalating specialization in individual disciplines. Students, parents, and politicians have increasingly focused their aspirations on vocationally-driven approaches to higher education. This has occurred while, at the same time, employers (especially in "high tech" areas) have emphasized that learning outcomes associated with an integrated education, such as critical thinking, communication (especially writing skills), teamwork, etc. are more, not less, desirable. The National Academies report recommends that higher education should intentionally strive to integrate knowledge in the arts, humanities, physical and life sciences, social sciences, and technology. Professors should help students understand the connections among these disciplines and recognize that all forms of inquiry are "branches

from the same tree," as Albert Einstein called them. We should teach our students that all human knowledge is fundamentally connected.

With the above considerations in mind, this volume expresses not so much the pedantic view of inoculating STEM research with humanities, as it conveys the views of individuals who are actually doing so, and who produce creative works that reveal the nature of how blending humanities and science can be effectively accomplished. In other words, these essays are written less with the academic approach than the applied, by people who have found ways to successfully harmonize these two great realms of human pursuit. In this sense, each chapter might even be considered a case study.

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The Integration of Humanities and Science

Richard C. Brusca

Why There Is a Need to Integrate Humanities and Science, in Teaching and in Practice

By the middle of the 19th century the divide between sciences and humanities had begun to be recognized, and it grew through the 20th century with deep consequences. Coincidentally, the term "scientist" also seems to have been coined in the mid-19th century, by Cambridge University historian and philosopher William Whewell. Most science studies tend to differ from most humanity studies in their use of a Popperian hypothetico-deductive framework, following a process of hypothesis formulation, generation of predictions, prediction testing (with a goal of falsification), controlled experiments that have repeatability, and strong quantification and statistical testing. In contrast, humanities research is dominated largely by qualitative information. In addition, in the natural sciences evolutionary questions tend to dominate; not so in humanities research.

The growing dominance of the sciences in public education in the Western World is one of the major reasons for the decline of humanities in higher education. In 1959, British scientist (a physical chemist) and novelist C. P. Snow [1905-1980] delivered his now-famous Rede Lecture in the Senate House, University of Cambridge. The influential lecture was subsequently published as *The Two Cultures and the Scientific Revolution*. The lecture and book expanded on an article Snow had published in the *New Statesman* in 1956, also

titled "The Two Cultures." The essence of Snow's ideas can be summarized by this oft-repeated passage from his essay:

> "A good many times I have been present at gatherings of people who, by the standards of traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity at the illiteracy of scientists. Once or twice, I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: *Have you read a work of Shakespeare?* I now believe that if I had asked an even simpler question—such as, *What do you mean by mass, or acceleration*, which is the scientific equivalent of saying, 'can you read?'—not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their neolithic ancestors would have had."

Snow's lecture condemned the British educational system as having, since the Victorian era, over-rewarded the humanities at the expense of science and engineering education—noting that these had been decisive in winning the Second World War. In contrast, Snow claimed that German and American schools prepared their citizens equally in the sciences and humanities, and better scientific teaching enabled these countries to compete more effectively in the modern age. Snow's speeches and writings had a profound effect on British public schools and lent support to a strong shift of instructional emphasis away from the humanities and toward the sciences. Even studies of the history of humanities and history of science seem to belong to two very different

cultures. Snow's views have been criticized as having driven a still deeper wedge between science and the humanities. Stephen Jay Gould (2003) argues that Snow's concept of "two cultures" is not only off the mark, it is a damaging and short-sighted viewpoint that has likely led to decades of unnecessary fence-building.

In the 20th and 21st centuries, only a few fields of academic study traditionally integrated science and the humanities (e.g., anthropology, psychology). In recent decades, only a few scientists/ humanists have worked comfortably across these two great arenas of human endeavor—think of E. O. Wilson, Stephen Jay Gould, Steven Arthur Pinker, Janisse Ray, Gary P. Nabhan, Richard Dawkins, Sam Illingworth, David Edwards, Alan Lightman, Steven L. Goldman, Oliver Sacks, and Brian May. May was lead guitarist for the rock band Queen, but also has a PhD in astrophysics from Imperial College London and in 2013 published a benchmark paper describing the nature of space dust found between the Sun and Mars. May was appointed a Commander of the Most Excellent Order of the British Empire in 2005 for services to the music industry and for charity work in animal welfare. He served as Chancellor of Liverpool John Moores University from 2008 to 2013, was a science collaborator with NASA's *New Horizons* Pluto Mission, and contributed to NASA's OSIRIS-Rex mission. He was knighted by King Charles III in 2023.

Of course, historically, the field of "natural history" encompassed both disciplines and the greatest scholars of the past whose work epitomized the innate ability to integrate humanities and science are familiar names, e.g., Leonardo da Vinci, Santiago Ramón y Cajal, Friedrich Schiller, Samuel Morse, Erasmus Darwin, Georg Forster, Johann Wolfgang von Goethe, Ernst Haeckel, Alexander von Humboldt, H. G. Wells, Henry David Thoreau, John James Audubon, Ansel Adams, John Steinbeck, Ed Ricketts, Aldo Leopold, Rachel

Carson, Edward Abbey, Ralph Eugene Meatyard, N. J. Berrill. Their work was so powerful that it changed the direction of thought in much of the Western World. John Steinbeck's [1902-1968] *Grapes of Wrath*—arguably the greatest novel in America's literary canon—exposed the story of Midwest soil erosion leading to an era of farming migrants that resulted in their exploitation by large farming enterprises in California. Rachel Carson [1907-1964] was one of the greatest humanists-scientists of the 20th century. In 1952, she sent her letter of resignation to the U.S. Fish & Wildlife Service requesting "retirement in order to devote my time to writing." With a series of courageous open letters she wrote, Carson held the government accountable for its shameless exploitation of nature. Her 1951 book, *The Sea Around Us*, taught readers environmental awareness through prose and science that ranged from the oceans primeval beginning to the latest scientific discoveries. It became a huge success, on the bestseller lists for eighteen months, that won both the National Book Award and the Burroughs Medal in nature writing and has been translated into 28 languages. The film version was released in 1953 and won an Oscar for Best Documentary. Her writing came from a gifted and literary place that walked the line between the scientific and the poetic. Carson's writing opened the door to a whole new genre of conservation books written for the lay public.

Just twelve years before her death, Carson met the remarkable Dorothy Freeman and the two developed a deep and loving relationship. Freeman became instrumental in helping Carson keep her struggles with depression at bay and continue writing. In the spring of 1960, just as she was finishing the draft chapters in *Silent Spring* (1962) dealing with the carcinogenic effects of chemicals, Carson was diagnosed with breast cancer. She died in 1964, shortly after her testimony before President John F. Kennedy's Science Advisory Committee that proved instrumental in establishing the first