Heroes for the Renaissance Engineer: Leonardo, Nabokov, Bach, and Borodin

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Abstract

Franklin W. Olin College of Engineering has attracted a student applicant pool gifted in science, mathematics, and the creative arts (theater, music, writing, and the fine arts). These burgeoning Renaissance engineers, already used to multitasking their various talents, fully expect to continue their interests in college, perhaps augmenting them as well. Dual talents in art and science regularly manifest themselves on the class lists of virtually all educators in science, mathematics, and engineering. Is it possible to offer them models for living and working — heroes — whose inimitable contributions to society stem in part from dual (and sometimes dueling) passions? This paper examines individuals who possessed extraordinary ability in the arts, mathematics, and science. It explores how their creative voices achieved resonance for generations, how at times their disciplines entwined, while at others they separated. Source documents provide the key focus for analysis and critical thought revolving about four figures in the fields of literature, art, and music: Vladimir Nabokov (writer and lepidopterist), Leonardo da Vinci (artist and anatomist), Alexander Borodin (composer and chemist), and J. S. Bach (composer, performer, and acoustician). Each of these achieved a profound self-sufficiency enabling the articulation and activation of work that revealed a singular vision; in short, an entrepreneurial streak runs through their lives, fueled by individuality and remarkable originality — an originality shaped in part by fluency in art and science. Engineering schools, long fond of pointing out the Renaissance engineers in their midst, might augment their support of such students and faculty by sponsoring classes that speak to these multitalented individuals, offering them mirrors for reflection and growth.

I. Introduction

Literature, Art, Music: Intersections with Science represents one such class. By introducing students to V. Nabokov (1899-1977), Leonardo (1452-1519), Johann Sebastian Bach (1685-1750), and A. Borodin (1833-1887), the class effectively provides mentors for the Renaissance engineer. It further demonstrates the power of "speaking two languages" and the inventiveness that can emanate from a deep understanding of two fields. This inventiveness manifests itself in Nabokov's literary and scientific design, Leonardo's pioneering work in comparative anatomy, Bach's invention of new instruments with desired acoustical properties, and Borodin's ability to juggle his work in music composition and the laboratory, while publishing in both fields and championing women's educational rights. He also invented at the interface of medicine and chemistry.

The benefits of such a course in an engineering environment might be summed up with the mnemonic CREATE:

Creative process illustrated in art, science, and their intersection
Revelatory passions that speak to generations
Enhancement of individual creativity
Active learning
Thinking through concepts, symbols, imagery, analogies, and design
Examples for reflection and development.

The following sections address each of these benefits, though in a different order from that given above. Rather, the flow arises from how the course segues from one study to the next, starting with those whose work most combined art and science (Nabokov and Leonardo) to others who either kept them as separate endeavors (Borodin) or abstracted from science only that part relevant to artistic practice (Bach).

II. Enhancement of individual creativity

"I kept wondering what do butterflies and moths have to do with Nabokov's literary output. I was so skeptical. And then after reading his novels, I realized they're everywhere." The student quoted above had just finished a crash tutorial on Lepidoptera, followed by reading assignments including *Speak, Memory* (1967), *The Gift* (1935-37, English translation 1963), *Lolita* (1955), and *Pale Fire* (1962). Nabokov wrote *Speak, Memory* as a remembrance of a life long lost but hardly forgotten. It follows his journey from privileged childhood in pre-revolutionary Russia to impoverished existence in postwar Berlin, emigre home to Russians fleeing the Bolsheviks. His autobiography closes in 1940 as he, his wife, and young son board a ship for America.

During his Berlin years, Nabokov wrote much of what he considered his finest Russian novel, *Dar* (The Gift). This was to be his last novel in his native tongue. Upon embarking in the United States, he made a conscious decision to write his future works in English, a language he had known since childhood. Nabokov considered *Lolita* and *Pale Fire* the best of his eight English novels.

A number of butterfly and moth families make appearances in these works — families with names like Lycaenidae, Satyridae, Nymphalidae, Pieridae, (representative of butterflies), and Sphingidae, Noctuidae, Saturniidae, and Geometridae, (representative of moths). These families fit into the taxonomic order as follows: class (Insecta), order (Lepidoptera), family, genus, species, subspecies. A definition only exists for species (the capability to interbreed and produce viable offspring), which means that classifications other than species, can stir intense debate. As part of the crash tutorial on Lepidoptera, students each choose a family and write its "biography," with an ear towards presenting the chosen family to the rest of the class in an engaging way. One example written by David Coleman, a graduate student at Tufts University, shows how immersion in an unknown topic can trigger a creative leap at once entertaining and informative.

Interview with Hawk

As I walked into the library, I nervously searched the room with my eyes, looking for my subject of the day. All my boss told me was that I'd know him when I saw

him. I had a 2:30 interview scheduled to cover the life and times of some guy named Sphingidae. I decided to look up the name while I waited for him to show up. It turns out that his name is derived from the word Sphinx, the ancient Egyptian character with a lion's body and a female's head. I also learned that it was a family of the Lepidoptera order.

Before I could say out loud, "Lepi-what?" I turned and saw him enter the room. He had a large, heavy body, pointed antennae, a long proboscis, and narrow wings. As I stood there watching him approach me, I wondered why he was called "sphingidae" and what the reference was to the sphinx. He met me at the table and we both sat. He held his wings over his body like a tent. I told him my name, and asked if he liked being called Sphingidae, or did he have a nickname like "Sphingie" or the "Sphing-meister." He laughed and replied that people call him "hawk moth" or "hummingbird moth." He got the name "hawk" because he can fly very fast, and he got the name "hummingbird" because he can also hover in flight. He uses this ability to sip nectar from flowers using the proboscis, or trunk, when he flies. I said that I would call him "Hawk" for short because that sounded cooler.

My first question for Hawk was about the early years and his upbringing. What made him the moth he is today? He explained that like all butterflies or moths, he went through four stages of life. He didn't get to know his mother very well because she left him orphaned during the first stage of life. He spoke of his mother having to search around with great care for a host plant to lay her eggs. She was afraid of being eaten by predators and stayed near plants, sipping their nectar for food. So Hawk spent the first part of his life on the underside of a leaf where he was hidden from predators and extreme temperatures. Even though his mother abandoned him, he felt that his correct placement near the host plant was a sign of her love, so he had no bad feelings towards her. As he entered the second stage and became an adolescent caterpillar, he had to eat his way out of the eggshell. He then moved from the leaf to a suitable resting site. He also found that he had brothers and sisters surrounding him. He had between 3 and 10 siblings (he said he was so concerned about eating, he couldn't remember). ... They all ate mostly at night under the cover of darkness. When the caterpillar senses disturbance, he rears up with his anterior segments arched, and his head facing the disturbance. This sphinx-like posture is where the scientific name Sphingidae is derived. Once a mature caterpillar, Hawk made off to find a suitable site to pupate.

His third stage of life took place under stones or within a loose cocoon on the surface of the soil, depending on how far the caterpillar can travel to find a safe place. This is where Hawk became the adult that he is today, changing from a caterpillar into the flying adult moth. ...

This was all well and good, but I needed some more personal information to spice up his interview. It was time to dig deeper and ask Hawk the more personal

> questions about sex, death, and religion. Concerning sex, Hawk said that since he is a nocturnal creature and can't rely on sight to find a mate, the females produce powerful airborne sex pheromones capable of 'calling' males from some distance. The male approaches upwind and immediately copulates. He said copulation can take anywhere between 2 and 20 hours, immediately gaining my respect and admiration. It occurred to me that I hadn't asked Hawk's age yet. I was surprised to learn that he had only been alive for about 40 days, and that he had about 10 days remaining to live. It seems that the life span of the adult Sphingidae is 10 to 30 days, depending on climate and feeding conditions. I gave my condolences and realized that it was time to end this interview.
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> As he headed out of the library, I thanked him for his time and remembered that I didn't ask him about his religious practices. He said that since his life was so short, moths don't practice religions because they spend most of their time looking for food from nectar flowers. However, he said that he did have a motto he lived by — "Drink the nectar out of life." I decided that was good enough, and as I watched him leave and stretch his eight-inch wingspan, I wanted to tell him that humans had a similar saying. But remembering that he was a nocturnal creature, I simply said, "Carpe Noctem."

In writing the above "Interview with Hawk," the student author pulled together many of the various sides that makes him such a creative individual — he loves to write, whether with music or words (and sometimes with both), he revels in analogic thinking and makes connections readily between disparate topics, and he embraces technical fields, conveying scientific information which he impishly laces with humor, all within the mock setting of an interview with a hawkmoth. Not only did he delight his classmates, he clearly enjoyed bringing his myriad talents into creating his "lep family" biography.

III. Thinking through imagery, symbol, metaphor, and design

After attaining some familiarity with the terms and individual families comprising a lepidopteran's world, students read *Speak, Memory*, *The Gift*, *Lolita*, and *Pale Fire*. But they do not approach these works amorphously. Rather, they read as detectives on a lit/lep hunt, seeking out all possible references to butterflies and moths and then classifying them according to function (descriptive, symbolic, metaphoric, etc.) What they find illuminates the role of Nabokov's other life — his passion for Lepidoptera — embedded within his literary life. This entwining creates imagery, as when he describes his fascination with

> hawkmoths, the jets of my boyhood! Colors would die a long death on June evenings. The lilac shrubs in full bloom before which I stood, net in hand, displayed clusters of a fluffy gray in the dusk—the ghost of purple. ... And suddenly it would come, the low buzz passing from flower to flower, the vibrational halo around the streamlined body of an olive and pink Hummingbird moth poised in the air above the corolla into which it had dipped its long tongue. Its handsome black larva (resembling a diminutive cobra when it puffed out its ocellated front segments) could be found on dank willow herb two months later.[1]

The Gift shares uncanny similarities to *Speak, Memory*, something the writer emphatically denies in his Foreword to the English edition (1963). As in the autobiography, an uninterrupted section of the novel concerns butterflies and moths, revealing the wonderment and delight these creatures stir in the protagonist and narrator, Fyodor Godunov-Cherdyntsev, as he relates what his naturalist father taught him:

> He taught me how to take apart an ant-hill and find the caterpillar of a Blue [a butterfly in the Lycaenidae family] which had concluded a barbaric pact with its inhabitants, and I saw how an ant, greedily tickling a hind segment of that caterpillar's clumsy, sluglike little body, forced it to excrete a drop of intoxicant juice, which it swallowed immediately. In compensation it offered its own larvae as food; it was as if cows gave us Chartreuse and we gave them our infants to eat.[2]

The role of Lepidoptera remains predominantly descriptive in *The Gift*, providing imagery to accompany the protagonist's father in his travels as a naturalist. By the time students undertake *Lolita*, they have more than enough direct examples of Lepidoptera infusing Nabokov's writing. In *Lolita*, far fewer exist; those uncovered include lepidopteral terms for names and places in the novel. Nabokov's passion for butterflies and moths did not cease when he emigrated from France to the States in 1940. He spent virtually every summer traveling across America in search of them.

Thus the verisimilitude of Humbert's and Lolita's trips across the United States from New Hampshire to Lepingville to Elphinstone brim with authenticity, though the place names often reflect his beloved taxonomic order. Nabokov's skill in capturing the pulse, or lack thereof, in 1950's America shows his lepidopteral activities enhancing his writer's world in indirect ways, something he puts to good use in framing the American landscape through which Humbert and Dolores Haze thread their way.

In *Lolita*, students see the descriptive function of Lepidoptera, so evident in *The Gift*, fading and its symbolic use ascendant. For example, a one-sentence paragraph — An inquisitive butterfly passed, dipping, between us — smoothly intrudes between two lengthy paragraphs describing a game of tennis between Humbert and Lolita. Just as the butterfly positions itself between paragraphs, Clare Quilty (the hedonist pursuing Lolita for his own designs) comes between Humbert and his charge.

When students take a step back and look at *Lolita* as a whole, the descriptive quote given earlier (concerning the larvae-eating caterpillar from *The Gift*) naturally comes back to mind. Nabokov's lepidopterans not only provide him with imagery, metaphor, and symbol, they also suggest a seed for the entire structural design of *Lolita*. Like the Lycaenidae caterpillar's barbaric pact with the ant colony (trading sweet juice for ant larvae), Humbert enters the Haze household, exuding a French charm that Charlotte Haze (Lolita's mother) finds irresistible. But like the Lycaenidae caterpillar, Humbert's only intent is to "feast" on her offspring.

In reading *Pale Fire* students find Nabokov throwing out lepidopteral nonsense so as to discredit his first person narrator, Charles Kinbote. By now quite familiar with butterflies and moths,

students spot these obvious misfacts. They see yet another side of the writer's use of deceit and mimicry, mirrored in various lep families, to achieve his distinctive design.

Of the myriad ways Nabokov could have structured and written his novels, he (as with most creators) converges on only one path through a given work, much as a circuit designer might choose one solution over innumerable others. Students experience the design of Nabokov's work, not only in his literary output, but also in his scientific papers on Lepidoptera. Faced with any number of ways to attack certain persistent problems in taxonomic classification, Nabokov devised his own tools. For example, he pioneered a new method for measuring and depicting butterfly wing patterns. He drew beautifully, a skill developed in his native Russia by his drawing tutors. According to the lepidopterist and nature writer Robert Michael Pyle,

> …no one before or since has undertaken the almost incredibly precise, scale-by-scale mapping that enabled Nabokov to untangle the relationships of pattern development and geographic variation in the orange-bordered Blues [of the genus Lycaeides].[3]

As a lepidopterist he authored nine journal papers (seven of them in *Psyche* and *The Entomologist*) that contributed to the science of lepidopterology, specifically in the taxonomic classification of the Lycaenidae family. He untangled the web of names associated with the orange-bordered Blues of the Northern Hemisphere, the Latin American Blues, and a set of Satyrs then called Neonympha. He did all of this work armed simply with a 1940's era microscope, a distinguishing eye, and tremendous perseverance. Two 21st century lepidopterists — Kurt Johnson and Zsolt Bálint — have evaluated Nabokov's reclassifications and summarize his achievements thusly:

> To anyone familiar with the immediate post-War seminal systematic work on tropical lycaenid butterflies [Blues, Metalmarks, Hairstreaks, and Coppers] of the New World, which comprise perhaps a quarter of all the world's butterflies, Nabokov is one of the four major names that come to mind, together with Comstock, Huntington and Clench.[4]

In Nabokov, students talented in art and science see an individual who maintained his twin passions throughout his life. They realize how part of his distinctive literary voice resulted from his fascination with Lepidoptera, how his fine arts sense, nurtured from boyhood, aided him in his scientific work, how his devotion to two fields (coupled with the requisite time demands of each) necessitated narrowing his scientific focus to areas where he felt he could make the greatest contribution. Perhaps most importantly, students connect with a multitalented mentor who by his example extols the virtues of pursuing one's passions, despite the inevitable demands on time and available resources.

III. Active Learning

Analogic thinking, the ability to conceptualize by making analogies, presents itself to students via Leonardo da Vinci. His anatomic studies show him doing just that when he draws side-by-side the hind limb of a horse, the hip and leg of a man, and the human skeleton of the hip and

thigh. He compares the bear foot to that of a human. These and other drawings credit Leonardo as the first to introduce the idea of comparative anatomy.

Scant knowledge exists about da Vinci. But a chronology of generally accepted facts describes a life spent in both art and science.[5] This chronology provides a critical foundation for understanding a man who remains a hero to students almost 500 years after his death. By familiarizing themselves with the chronology, they are able to attach additional information onto a framework, whether studying the thousands of secondary sources on him, the world in which he worked — Renaissance Italy — or arguing other points of view. One way to achieve this familiarity takes advantage of Giorgio Vasari's 1568 account, *Lives of the Artists*.[6] A competent artist and friend of Michelangelo, Vasari found himself uniquely positioned to write about painting and painters. He supplies a well-written, mostly anecdotal account of Leonardo's life. (Vasari was only eight years old when da Vinci died.) Unfortunately, errors abound. Students uncover these discrepancies between fact and fiction by carefully reading Vasari's account in tandem with the more accurate chronology. In doing so, they learn the known facts concerning da Vinci's life and build the scaffolding for later information.

Both Leonardo and Nabokov provide unambiguous examples of creators whose pursuit of science for science's sake competed with their various artistic projects. Often, such devotion to science enhanced their art, yet it also encroached on the time allocated to painting and writing, respectively.

In contrast, the case of J. S. Bach is not so clear-cut in terms of his scientific ties. To complicate matters, not much information exists about him in any facet of his life. However, an excellent compendium of original sources all pertaining to Bach, either written by him or by others about him, can be found in *The New Bach Reader*.[7] Students become detectives as they peruse the documents, searching for evidence that answers the question: To what extent did Bach have an ability for, or knowledge of science and mathematics? Students frequently cite an account provided by Bach's son, Carl Philipp Emanuel Bach, that demonstrates Johann Sebastian's acoustical expertise:

> He came to Berlin to visit me; I showed him the new opera house. He perceived at once its virtues and defects (that is, as regards the sound of music in it). I showed him the great dining hall; we went up to the gallery that goes around the upper part of that hall. He looked at the ceiling, and without further investigation made the statement that the architect had here accomplished a remarkable feat, without intending to do so, and without anyone's knowing about it: namely that if someone went to one corner of the oblong-shaped hall and whispered a few words very softly upward against the wall, a person standing in the corner diagonally opposite, with his face to the wall, would hear quite distinctly what was said, while between them, and in the other parts of the room, no one would hear a sound. A feat of architecture hitherto very rare and much admired! This effect was brought about by the arches in the vaulted ceiling, which he saw at once.[8]

In a letter written one year later, C.P.E. Bach expands this theme:

> As a result of frequent large-scale performances of music in churches, at court, and often in the open air, in strange and inconvenient places, he learned the placing of the orchestra, without any systematic study of acoustics. He knew how to make good use of this experience, together with his native understanding of building design so far as it concerns sound; and these were supplemented in turn by his special insight into the proper design of an organ, the disposition of stops, and the placing of the same.[9]

And yet in the identical letter, C.P.E. writes that his father "was no lover of dry, mathematical stuff," in reference to J. S. Bach's joining the Society for the Promotion of Musical Sciences. Among other topics, the Society discussed various improved methods of tuning. Handel joined its membership in 1745 and Bach followed in 1747. J. S. Bach provided a musical "proof" of the validity of the well-tempered system of tuning[10] by writing *The Well-Tempered Clavier*, a set of 24 Preludes and Fugues in every major and minor key (1722). He followed this by a second book of 24 in 1742.

Bach's ability to abstract from his acoustical knowledge all that he needed for his musical concerns takes an inventive turn when students read about his viola pomposa, an instrument tuned like a cello but with an added string at the top. Bach designed the viola pomposa to be somewhat larger than a viola, attached with a ribbon so that it could be held on the player's arm in front of the chest. He invented the instrument to provide a less obtrusive accompaniment to violin solos than a keyboard (which might obscure the solo with full, harmonic accompaniment) or a cello (considered too distant a relation to the violin).[11]

IV. Revelatory passions that speak to generations

Sometimes nothing says it better than a poignant letter or an extended scribble in a notebook. Providing students access to original sources opens their worldview, allowing them to make their own discoveries, to say it in their own words. So amidst a compilation of anatomical writings gathered from Leonardo's notebooks, students eventually encounter a note that invariably causes them to pause:

> And you, who say that it would be better to watch an anatomist at work than to see these drawings, you would be right, if it were possible to observe all the things which are demonstrated in such drawings in a single figure, in which you, with all your cleverness, will not see nor obtain knowledge of more than some few veins, to obtain a true and perfect knowledge of which I have dissected more than ten human bodies, destroying all the other members, and removing the very minutest particles of the flesh by which these veins are surrounded, without causing them to bleed, excepting the insensible bleeding of the capillary veins; and as one single body would not last so long, since it was necessary to proceed with several bodies by degrees, until I came to an end and had a complete knowledge; this I repeated twice, to learn the differences.
>
> And if you should have a love for such things you might be prevented by loathing, and if that did not prevent you, you might be deterred by the fear of living in the

> night hours in the company of those corpses, quartered and flayed and horrible to see. And if this did not prevent you, perhaps you might not be able to draw so well as is necessary for such a demonstration; or, if you had the skill in drawing, it might not be combined with knowledge of perspective; and if it were so, you might not understand the methods of geometrical demonstration and the method of calculation of forces and of the strength of the muscles; patience also may be wanting, so that you lack perseverance. As to whether all these things were found in me or not, the hundred and twenty books composed by me will give verdict Yes or No. In these I have been hindered neither by avarice nor negligence, but simply by want of time. Farewell.[12]

In today's refrigerated, climate-controlled environments, it becomes unthinkable to imagine the stench and deterioration Leonardo experienced for the sake of knowledge and his passionate pursuit of it. The above passage demonstrates his fundamental belief that all of his abilities — drawing, knowledge of perspective, patience, mathematical ability, perseverance — contribute to his understanding of the human body in a way that may enrich those who eventually read his work.

Similarly, when da Vinci speaks of what it takes to be a painter, students cannot miss the focus and all-encompassing nature of his sense of perfection. Leonardo's love for what he does borders on obsession. The perfectionism he brings to his projects both inspires and warns. In painting *The Last Supper*, he takes a snapshot of Christ and his disciples at the very moment Jesus has said, "One of you will betray me." Leonardo's depiction of this event stands alone in the history of art; no one had ever captured the dynamism, the inherent movement of such a scene. Yet he left the face of Christ unfinished. He could not reach with mere hands — even his hands — the perfect embodiment of that face as held in his mind's eye.

Vladimir Nabokov also exhibited perfectionist traits but his sense of perfection did not hinder his ability to complete work. In a passage somewhat reminiscent of Leonardo's work ethic, Nabokov's thoroughness and dedication to Lepidoptera sustain him through fourteen-hour days, many of those hours hunched over a microscope. He writes in a 1944 letter to the literary critic Edmund Wilson, at the time a close friend:

> I know, however, quite well that the appalling condition of my purse (a few hundred dollars melting in the bank, my miserable museal salary and some 800 which I shall earn next semester at Wellesley) is my own fault, i.e., I am devoting too much time to entomology (up to 14 hours per day) and although I am doing in this line something of far-reaching scientific importance I sometimes feel like a drunkard who in his moments of lucidity realizes that he is missing all sorts of wonderful opportunities.[13]

Both Leonardo and Nabokov made tremendous sacrifices for their scientific passion, some of which are only touched on here. Students come to appreciate "what it takes" to maintain such pursuits in the face of financial and physical obstacles, not to mention hard questioning by others and the self-doubt that so often accompanies pioneering ventures.

When students pour over the assembled documents by or pertaining to J.S. Bach, ostensibly searching for those with any scientific content, they cannot help but pause over a few that seem incongruous with the name of Bach. In 1705, the minutes of a church consistory show Johann Sebastian involved in a brawl with a student. Six months later, the same consistory rebukes him for his prolonged absence and improper playing; the following year, they take him to task once more, asking him "by what right he recently caused the unfamiliar maiden to be invited into the choir loft and let her make music there."[14] But other documents strike students with their poignancy. For example, in 1717 Bach accepted a position as conductor in the court of Prince Leopold of Cothen. It offered him new opportunities and challenges as a musician. There was only one problem: he still worked for the Duke of Weimar. When Bach sought his release from service, the Duke refused to let him go. Bach continued to insist. The court secretary wrote a report of this battle of wills:

> On November 6, [1717], the quondam concertmaster and organist Bach was confined to the County Judge's place of detention for too stubbornly forcing the issue of his dismissal and finally on December 2 was freed from arrest with notice of his unfavorable discharge.[15]

In other words, Bach went to jail rather than forego an opportunity for greater musical satisfaction in Cothen. What did he do during that month in jail? Not being one to waste time, he may have worked on his *Orgel-Buchlein* which he entitled towards the end of 1717 as the

> Little Organ Book (with 48 realized chorales),
> In which a beginner at the organ is given instruction in developing a chorale in many divers ways, and at the same time in acquiring facility in the study of the pedal since in the chorales contained therein the pedal is treated as wholly obbligato.[16]

One day in the life of Alexander Borodin shows a thorough commitment to his twin passions — music and chemistry. His future wife Ekaterina Sergeevna Protopova recalled their first meetings and the extent of his day:

> We were often together. His day was usually arranged as follows: From five in the morning till five in the afternoon he was in his laboratory; from five till eight we went for a stroll in the hills. What pleasant walks these were; we must have talked about every subject under the sun. From eight or nine in the evening until midnight we had music in the pension.[17]

Borodin, able and willing to work long hours, published 40 journal papers from 1858 (the year he defended his thesis) until 1886 (two years before his death at 54), including five contributed to the proceedings of various conferences. Between 1872 and 1876, he avoided experimental investigations that demanded continual work in his laboratory at the Medical-Surgical Academy in St. Petersburg. This was due in part to his intense involvement in championing the educational rights of women in Russia. He organized the higher medical courses for women at the Medical-Surgical Academy. Only in 1876 did Borodin return to prolonged lab work. At the

request of his fellow physicians, he invented a method for determining quantitatively the amount of urea in urine. In clinical urinalysis, Borodin's method is now known as Ambard's method.[18]

Clearly, all four of these artist/scientists possessed enormous capacity for work, fueled in part by the stimulus of what they were creating, regardless of discipline. They profoundly cared about their various intellectual pursuits; the perfectionism they embodied in one domain inevitably transferred to the other. And they devised slants on their work which revealed their inventive natures; specifically, Nabokov's technique for recording butterfly wing markings, Leonardo's juxtaposition of human and animal anatomy (thus initiating comparative anatomy), Bach's viola pomposa, and Borodin's method for urinalysis.

V. Creative process illustrated in art, science, and their intersection

Of the four individuals discussed above, Borodin by far kept his artistic and scientific worlds apart, moving from one to the other as time and inclination permitted, all within a day's work. Though his musical output contains far fewer works than most composers, those he did manage to complete still grace concert halls and the opera house. These include two symphonies (he died while working on the third), two string quartets, and the opera *Prince Igor*, among others. In chemistry, Borodin was the first to work out the condensation of organic compounds, in his case, the aldehydes, a class of highly reactive organic compounds obtained by oxidation of primary alcohols. His research led to the chemical synthesis of resins that could be used in place of natural shellac.

By contrast, Bach focused all his considerable talents and energy into musical composition and performance. Johann Nikolaus Forkel (1749-1818) published the first biography of Bach in 1802. He based his monograph on information provided by musicians who had known Bach firsthand. Forkel says of Bach, "In general, his penetrating mind did not fail to notice anything which had any kind of relation to his art and could be used for the discovery of new artistic advantages." He also points out Bach's "minute knowledge of the construction of the organ and of all the single stops."[19] Indeed, several documents mentioning Johann Sebastian detail his role as an expert on organ construction, where an understanding of wind pressure, metallurgy, and spring mechanisms is evident.[20] Bach apparently directed whatever scientific and mathematical talent he possessed to better serve his art. He received a solid education, finishing his general studies in 1699, the lone 14-year old in a class where the average age was 17.7 years.[21]

For Nabokov and Leonardo, the boundaries between their artistic and scientific selves proved both distinct and fluid. It has already been shown how Nabokov's Lepidoptera infused his literary works via symbol, imagery, and metaphor, as well as on the structural design level. Yet he also published a number of scientific papers, several of which proposed new taxonomic classifications for the Lycaenidae family. These findings have recently been verified by lepidopterists using far more sophisticated instruments than the basic microscope employed by Nabokov. His science affected his art, and his artistic abilities enabled him to come up with the tools necessary to support his scientific theories. Nabokov, a perfectionist with the written word, carried that regard for the telling detail into his taxonomic studies. Brian Boyd, whose two-volume biography of Nabokov remains the definitive account, captured the author "as someone who always valued the individuating detail," placing him as a "splitter," a taxonomist who

recognizes and elevates distinct differences between types, as opposed to "lumpers" who tend to blur such differences into more generalized types.[3] As an author, Nabokov possessed a discriminating eye and as a lepidopterist, colleagues praised him for the same "good eye."

Like Nabokov, Leonardo's science fueled his art and his art fueled his science. His anatomical study, at first undertaken to enhance his portrayal of the human form, eventually takes on a life of its own. He pursues anatomy for anatomy's sake. Of course, his extraordinary skill with pen and pencil convey the science behind the human body in a way never seen before nor since.

VI. Examples for reflection and development

The degree to which these artist/scientists worked and the creative energy they brought to their various fields both inspires and motivates. For those students already working towards a goal, having contact with a long ago hero who, in addition to supreme inner gifts, pushes ever further, can serve as a lifetime model. For students who are not as motivated, but nevertheless find themselves searching for meaning in their lives, these four can stimulate growth and transformation within their current worldview. Their example can take young engineers on a journey that may transcend what at the moment seems possible.

VII. Conclusion

Literature, Art, Music: Intersections with Science introduces four individuals who pursued paths of varying degrees in science and art. For two of them — Vladimir Nabokov and Leonardo da Vinci — science gelled with art, resulting in expressive, inimitable voices. Alexander Borodin, on the other hand, maintained two separate professional lives, one in music, another in chemistry. Extraordinarily productive in several areas, including chemistry, women's educational rights, and music, he could no sooner give up one than relinquish his very being. His passions in art and science remained separate entities throughout his short life, perhaps inevitably so, given the absence of any natural parallels between music and chemistry. By comparison, the ties that exist between anatomy and art, or between Lepidoptera and literature, seem more obvious. The other composer in the group, J. S. Bach, focused all his resources toward music. For him, any knowledge he had, regardless of the field, became a servant to his musical goals. Science for science's sake, so apparent with Nabokov, Leonardo, and Borodin, held no meaning for Bach.

For students, the process of thinking through their own life experiences, while becoming intimately acquainted with such models of multidisciplinary thought, effectively holds up a mirror in which passion, hard work, resourcefulness, and imagination play out before their eyes and ears. These individuals teach much to any who enter their worlds, providing singular models for life and work, while triggering inquiring minds in unexpected ways. They offer particularly meaningful paradigms to those engineering students talented in both science and art — the Renaissance engineers so often noted in our colleges and universities. By providing enhancement opportunities that target these students, educators might unleash the greater potential within. These Renaissance engineers already possess two strong suits, fluency in art and fluency in science. Each of these languages possesses a rich and powerful vocabulary that

throughout history has inspired some of humankind's greatest achievements. Certainly they already inspire creativity in many of the nation's finest students.

By cultivating the Renaissance engineer early on, educators can allow that creativity to deepen and grow. This paper offers one step in that direction — a class connecting engineering students with those who moved the human condition further by virtue of their own fluency in the languages of art and science. Aided by an entrepreneurial spirit that pushed them to articulate their own visions, then bring these works to fruition, Leonardo, Nabokov, Borodin and Bach present heroic models to students at a critical time in life, as they prepare to embark on futures that will hopefully tap all of their gifts, not just a small subset. In cultivating the Renaissance engineer, colleges and universities expand the possibilities for gifted students, not to mention society at large.

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