Poetic Science: Bidirectional Reflection in Science and Medicine

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Perm J 2019;23:17-177

E-pub: 07/08/2019

https://doi.org/10.7812/TPP/17-177

ABSTRACT

The arts are making their mark in science, technology, engineering, arts, and mathematics/medicine (STEAM). Integrating creative expression—poetry and other visual and performing arts—can help clinicians, scientists, and others use familiar social constructs to embody science and medicine, in what may be termed *poetic science*. Poetic science imbues bidirectional reflections of science and medicine on the clinician or scientist or other inquisitor, creatively engaging the learner's brain cells as mirrors. This ultimately leads to a subjective perspective on the understanding or the proposition of underlying principles. Such an approach is encouraged here with poignant examples that can be accessed publicly online and used widely by readers, teachers, learners, clinicians, scientists, students, and others.

INTRODUCTION

Medicine and the sciences are in some ways a language spoken by nature, the human body, and everything else around us. Children can translate the sciences into their own language through writing, dancing, drawing, and singing their understanding of the world.[1] Their stories contextualize their experiences, and keeping science journals helps them explore and refine their own thinking processes.[1] Just as children interpret language freely,[1] so too should clinicians, scientists, and other learners of all ages interpret the sciences as a reflection of their subjectivity, and translate science into a language that can make an indelible mark on their memories (Figure 1). Imagination, which is cultivated by poetry, is thought to be a necessary stimulus for really good work in original research.[2] It has even been suggested that a poet be employed as a permanent staff member of research laboratories.[2] The poet would serve as a man of imagination to greatly assist the man of fact.[2]

Literary and scientific discourses are indeed distinct beasts, yet a partnership between the majestic beasts can create beauty. This beauty exists in ambiguity, as described in the following sentences. Interpretation of poetry and other forms of creative expression is often left to the recipient. Similarly, subjective interpretation of the objective data in science or medicine is often left to the clinician or scientist. This subjectivity can present ambiguity, as 2 scientists or clinicians can have varied opinions from their own professional frame of reference after interrogating the same data. As they view the data, their methods of discovery and problem solving benefit from both metaphor and analogy. Thus, the pursuit of medicine and science involves both objective and subjective aspects.[3,4]

Lyrical presentation of the sciences and allowance for subjective expression of objectivity can facilitate deeper understanding and learning.[5-7] Indeed, such companionship between the subjective and the objective, in a sense between complex equals in their own right, can deepen experiences in medicine, in sciences, and in life (Figure 2 and Appendix A. Creative Brain[a]). The partnership or companionship can form a bridge between body and mind, the physical and the intellectual, the matter and the mind,[8] thereby increasing divergent thinking skills and creativity.[9] Such a collaboration forged between poetry (or other forms of creativity) and medicine or the sciences[10] can be termed poetic science (see Appendix B. Glossary[a] and Sidebar: Poetic Science: Reflecting Shape and Form). Poetic science refers to the art form, as well as the tangible creative work itself, and the actual practice of creative expression. Various forms of poetic science as a creative medium are currently in use as a means of informing understanding, interpretation, and learning of the objectivity and subjectivity in science or medicine; various other authors, tutors, and learners have produced creative expression of science and medicine.[5,10-27]

In the poem in the Sidebar: Poetic Science: Reflecting Shape and Form, when the expectation that poetry and various sciences have to be mutually exclusive is set aside (by "removing the gate between the left and right brain"), poetic science can be created. This allows "science to tread poetry's terrain," by calling on several skills common to both. The substrates for creative expression of science are theoretically wound onto a spool (shape of the *poetic science* poem observed from top to bottom) as they "converge on the brain stem." Such substrates include critical skills such as the use of metaphors, imagination, creativity, and analysis.[10] Using poetry (or other forms of creative expression such as visual or performing arts) to express biomedical or scientific principles results in several outcomes. The poetic scientist improves those common skills, thinks more deeply about interpretation of medical and scientific observations, probes literature to ensure that the creative expression is evidence based, and often thereby discovers or comes to understand a new truth that was previously unrecognized or unrealized. As the thoughts and ideas are conducted along the nerve fibers like threads, sparks fly, and flashes of light emerge (scintillation), as lightbulbs turn on in science and medical classrooms. Poetic science therefore interweaves or sews together 2 kinds of disciplines in much the same way that an orchestra makes cohesive unique music from organizing sounds and talents from individual instruments and artists.

Philosophy and mythology both explain how medicine or science and poetry or other forms of creativity were once presumed communal.[28,29] Collections of medical poets or poetic physicians spanning thousands of years demonstrated the historical friendship and camaraderie between medicine/science and poetry or other forms of creative expression.[28] Yet, through the ages, distance grew between

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Keywords: poetic science; poetry; science, technology, engineering, arts, and mathematics/medicine; STEAM

the practice of science/medicine and efforts at creative expression. For decades and perhaps centuries, physicians were ridiculed or attacked for writing poetry; poetry and medicine were assumed incompatible, and people were assumed possibly efficient at only 1 subject, not 2.[28,29] Nevertheless, physicians and scientists continued to compose poetry and prose to express emotions and thoughts of ease, disease, habits, hobbies, and culture.[28]

Thankfully, as most things do, perspectives on medicine and poetry have come full circle. After having made a 360-degree survey of interactions between medicine and poetry, it is probable that creative expression in medicine is now experiencing its "latter rain." One of the first physicians to carefully craft a poetic piece that was well received publicly happened to write about relationships between spirituality or religion and science or medicine.[28] Another physician who was credited with writing poetically was a spiritual man named Luke, from early in the first century AD. Now that we have come full circle, perhaps we can also use an analogy from spirituality to help us understand relationships between creative expression and science or medicine. In Luke's time, the "latter rain" was expected to be more glorious than the "former rain." Perhaps now in the era of poetic science, we may be experiencing the "latter rain" of professional society's embrace of the age-old friendship between science/medicine and poetry or other forms of creative expression. In other words, we may be the ones to experience, advocate for, and restore a public permanence of harmony between science/medicine and creative expression.[29]

After all, poetry and science/medicine are more than "just friends." Poetry and science/medicine can reflect each other so intimately that if one does not look closely, one might wonder where one ends and the other begins. Both poetry and medicine have been credited with astute dependence on imagination and spontaneity for discovery, creativity, and propagation of beauty and truth.[2,28] Poetry is thought to help physicians and scientists make connections between isolated findings in science or medicine,[2] in part by way of analogy, but primarily by considering new discoveries or creative output in the context of what is already known, felt, or understood.

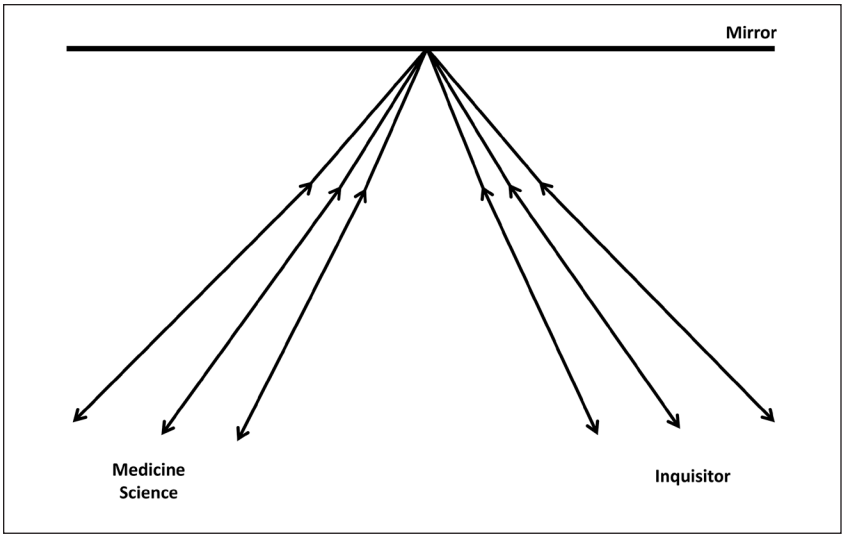

Figure 1. Poetic science: Reflections on science/medicine. Poetic science involves bidirectional reflections on science and medicine with an inquisitor or learner.

POETIC SCIENCE: BIDIRECTIONAL REFLECTION

The scientist or physician who translates poetry from other languages to his/her own language may be thought of as a "bringer-over" or ferryman (or ferrywoman, ferryperson), who transports the cargo embedded in the poem to a new language[2] or a new form of expression. In the same way, the scientist or physician who is writing a poem de novo is also serving as a "bringer-over" or ferryman. The embedded cargo in this case is a more profound understanding of science or medicine, indeed a reflection of the sciences or medicine (Figure 1). This principle is not limited to poetry. Leonardo da Vinci is credited with the comment that a painting is silent poetry to be seen, poetry is a painting to be felt, and both are reflective art. Thus, various forms of creative expression not confined to poetry alone are captured in poetic science. The cognitive aspect of literary activity increases insight and continuous reflection on our work[30] and our practice of the art of medicine. It is this attribute that allows the learner to project his/her suppositions onto medicine or the sciences, with a reflected wave that makes an indelible mark on the learner's consciousness (Figure 1).

It is most important to recognize that the reflection in poetic science is bidirectional. Clinicians, scientists, and others reflect on science and medicine by interrogating objective data and composing prose, poetry, or other media of creative expression to record subjective expression of the data. In other words, we record in our own words what we have absorbed. We absorb some of the waves that emanate from medicine or science; some of the waves are reflected from us onto medicine or science itself. Because of this, as we seek the truth in medicine or science, we impose on the truth our own understanding, interpretation, frame of reference, and perspective in what we record. Does this mean that the truth in medicine or science changes from person to person? No, the truth itself is absolute, but our subjective interpretation of the objective truth is not. In this way, poetic science involves bidirectional reflection in science and medicine (Figure 1).

Bidirectional reflection is not unique to clinicians or scientists in science or medicine. More broadly, bidirectional reflection is relevant to everyone in any walk of life. For example, a proposed mirror neuron system in the brain helps mediate audiovisual interaction and interpretation between musicians and their audience.[31] The mirror neuron system fires with both observation of an action and execution of the same

action.[32] By analogy, poetic science in the form of music or literature tells a narrative that unfolds in time with temporal stress and repetition[33] that can be followed to learn more about its interpretation of medicine or science through synthesis of the arts. Perhaps lyric, verse, dance, prose, or any art form mediates the projection of the learner's subjectivity onto medicine or science and the reflection of medicine or science onto the learner's conceptual framework and understanding (Figure 2). This too can apply to any practitioner or professional in medicine or science (medical and graduate students, nurses, chaplains, ethicists, hospital administrators, etc) or professionals in other fields as well.

Notably, the medial prefrontal cortex, an area at the front of the brain, is thought to activate during freestyle (spontaneous unedited) rap and generation and revision of poetry, consistent with sustained motivation during the freestyle or poetry-writing process[34,35] (Figure 3). This area also activates with higher technical facility in poetry writing.[34] The dorsolateral prefrontal and parietal executive systems, located just behind the medial prefrontal cortex, engage more strongly during poetry revision and are attenuated during freestyle rap and poetry generation, suggesting more cognitive control during revision relative to spontaneous generation[34,35] (Figure 3). The dorsolateral prefrontal and parietal executive systems are also thought to be activated with a greater extent of innovation in the poems[34] and with an impact of music on associative strategies for successful encoding and retrieving of verbal material.[36] Both areas of the brain are also associated with other regions relevant to the creative process in a network linking motivation, language, affect, and movement.[34,35] Similar networks have also been demonstrated to be activated during aesthetic assessment of paintings,[37] improvisation by jazz musicians,[38] as well as dance,[39] architectural space,[40] and reading literature or listening to music produced by others.[33,41] In the same way that the creative process can be mapped onto the brain, the brain and its disorders can also be mapped or mirrored in creative expression (see Appendix C. I Love the Spine Neck,[a] Appendix D. A Delicate Dance,[a] and Appendix E. Ataxic MatchMaker[a]). One could imagine that the brain (or any other topic in science or medicine) and the creative expression could be placed figuratively as parallel mirrors (or "infinity mirrors"), with the potential for infinite reflection and recall in an ideal world; 2 mirrors placed in parallel can give a seemingly unending series of reflections that progressively become smaller and smaller toward infinity.

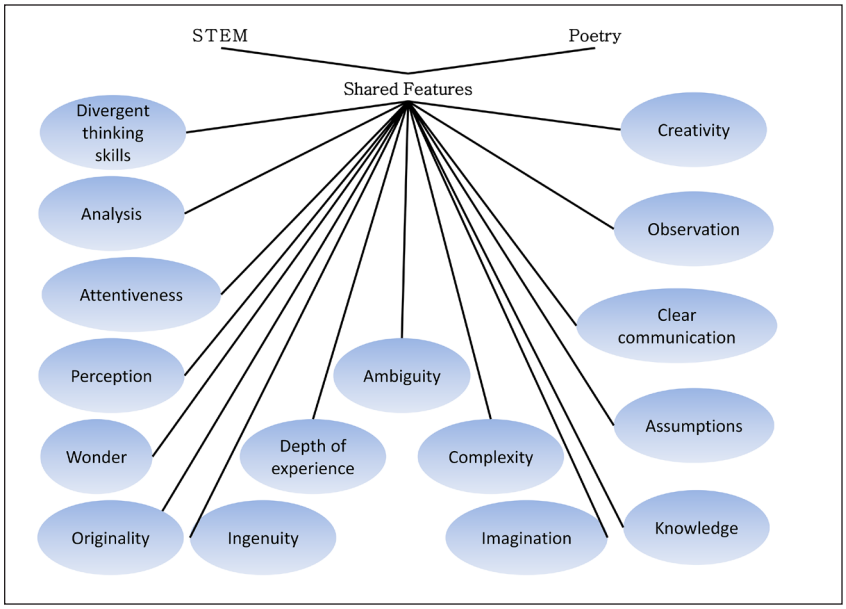

Figure 2. Shared features of poetry with science, technology, engineering, mathematics, and medicine (STEM). Poetry has myriad characteristics in common with STEM, including observation, perception, attentiveness, wonder, ambiguity, complexity, assumptions, divergent thinking skills, analysis, depth of experience, clear communication, creativity, originality, ingenuity, imagination, and knowledge.[1]

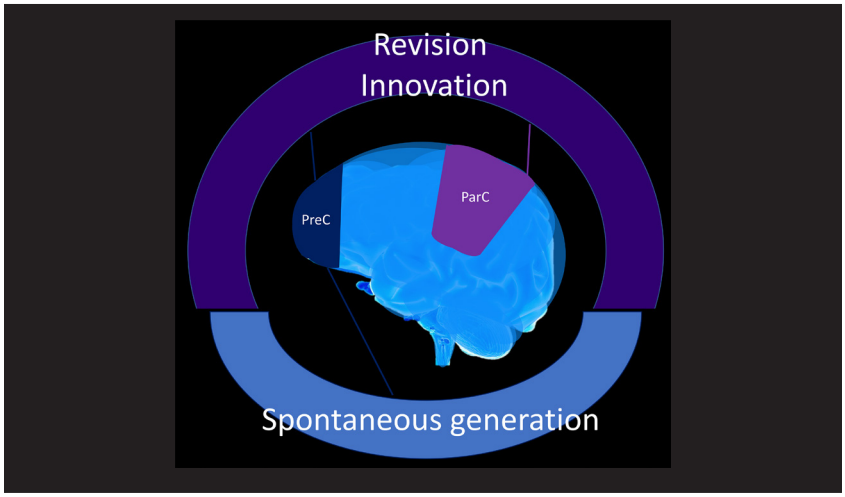

Figure 3. Poetic science: Poetry mapping onto the brain. Poetry can be mapped onto the brain during functional imaging, with primarily spontaneous generation of poetry mapping to the medial and dorsolateral prefrontal cortex (PreC), and revision and innovation of poetry also mapping to the parietal cortex (ParC).[34,35]

POETIC SCIENCE: COLLECTION

When one learns of writing poetry about medicine or science, often one beams in amazement at the possible merging of the 2 fields. This interaction of poetry and medicine or science in alliance for discovery[20] can be illustrated in a variety of creative science collections, such as a poetic science collection that addresses

subjective and emotional aspects of a variety of problems in science and medicine. As with other examples, such a collection enriches understanding and encourages interpretation by providing several poems written about or inspired by experiences in medicine or the sciences. One such collection is provided as an online resource to supplement this article:

1. Poetic Science STEAM Seminar Video Series: http://bit.ly/2i1jg2D, http://bit.ly/2DKXElq (audio version: http://bit.ly/2GoJfZV);
2. Poetic Science STEAM Slidesets: http://bit.ly/2fFX4dw, http://bit.ly/2i0mN0Z, http://bit.ly/2vDuGww.

This poetry collection was initiated in response to a universal movement recognizing the value of poetic science. The poem "Coincident Incident" was written at an annual conference sponsored by the American Society for Cell Biology (see Appendix F. Coincident Incident—Extended[a]). In December 2007 in Washington, DC, competitors were given 3 minutes, a microphone, a stage, and an audience composed of hundreds of conference attendees. Thirty minutes before the start of this science creative expression competition called "Cell Slam," the author finally sat and wrote down poetic science inspirations. In those moments, the poem "Coincident Incident" was birthed. In "Coincident Incident" (see Appendix F. Coincident Incident—Extended[a]) the author suggests an analogy between 1) arriving at a restaurant while the kitchen is still open and being able to be served a meal within a short time window before the restaurant closes and 2) an influx of extracellular calcium into the cerebellar Purkinje nerve cell cytoplasm (inside a cell at the back of the brain responsible for coordinating one's movements). This influx occurs through cell membrane-bound calcium channels before the inositol trisphosphate (IP3; a protein that regulates calcium levels in the brain cell) and calcium signals mediated by the IP3 receptor fade away, while the 50-millisecond to 100-millisecond time window is still open.[42,43] The opportunity for a meal is likened to the opportunity for supranormal calcium release, elucidated by biomathematical modeling. The poem describes the importance of the coincident incidence. The calcium refers to the author and a friend (or vice versa); the nerve cell represents the restaurant; the calcium signals mediated by the IP3 receptor refer to the meal prepared in the kitchen of the restaurant; and the short time window during which the IP3-mediated calcium signal is available refers to that time window between the start of the poem and the closing of the kitchen at the restaurant. This poem captures just 1 example of coincident incidence, which is a pervasive phenomenon in medicine and science.

The result for the poem "Coincident Incident" was educational, entertaining, hilarious, and much too long (see Appendix F. Coincident Incident—Extended[a]). The Cell Slam master of ceremonies danced in front of the stage to encourage the presenter to abandon the task. Even though the poem would be disqualified for lasting 5 minutes, the audience enjoyed the lyrical presentation and heartily expressed appreciation during and after delivery. The master of ceremonies jested that the reviewers might suggest splitting the poem into 2 manuscripts—1 for the preamble leading up to the restaurant, and the other an abridged version (see Appendix F. Coincident Incident–Abridged[a]) describing the analogy between 1) arriving while the restaurant's kitchen is still open and 2) calcium influx occurring at just the right time! That narrative is nostalgic of the spirited tenacity that promotes success in education and research. Therefore, the process of poetic science can literally and figuratively recapitulate and truly reflect the author's own experiences as a medical and graduate student, then as a medical resident and clinical and postdoctoral fellow, and now as an instructor and faculty in medicine and science.

POETIC SCIENCE: TRUTH TELLING

Similar to the author, but of much more prominence and eminence, Ralph Waldo Emerson's career included a series of lectures on the sciences. Emerson lived out his vision of poetic science, unifying many themes in the heart of American culture including ethical social practice, moral law, and sacred truth.[44] Indeed, the truth must be delineated in one's mind to write thoughts about medicine and science in the form of poems or other literary media. As each line of a poem is written, one must ponder whether the thought was true or instead simply caused by imagination. Such pondering can lead one back to reviewing scientific literature, experiment logs, or biomathematical simulations to see whether the written lines can be left as they are, or whether corrections must be made. The process of truth seeking therefore complements and may even precede communication of ideas on paper or digital media. The underlying premise for creative expression then is truth, or perception of truth—truth that is not discounted by biomathematical or wet-laboratory experiments but is, in fact, suggested and supported by these methods. Thus, poetic science can be a form of truth telling. Indeed, the ultimate objective for both artists and scientists, and also good physicians, is to pinpoint the truth and communicate this clearly and succinctly to others for appraisal.[45,46]

For physicians, patients are the primary appraisers and recipients of our truth

Poetic Science: Reflecting Shape and Form

Poetic Science

Removing the gate between left and right brain;
Allowing Science to tread Poetry's terrain.
Allowing the signals from both hemispheres
to simultaneously converge on the brain stem;
Poetry and Science traveling in tandem.
Down the spinal cord, released from the fingers.
An effervescent sense of partnership lingers.
Poetic Science harmonizes coordination,
Akin to the conduction of an orchestra's scintillation.

telling. It is imperative that we appropriately and closely inspect the objective and subjective data presented to us by patients or clinical colleagues (as we would a work of visual, fine, or performance art), to accurately diagnose and prognosticate the patient's condition. Although analogy and metaphor can be useful in this endeavor, imagination, creativity, and careful observation are also key. Once the diagnosis and prognosis are determined, this truth must be usefully communicated to the patient. For many medical conditions, prognostication can be riddled with uncertainty. This is especially the case when enrolling patients in clinical trials. Because of randomization, clinicians are unable to tell patients upfront whether they will receive the investigational intervention vs a placebo or sham. Even if patients are randomly assigned to receive the investigational intervention, each individual's outcome remains uncertain, or "investigational." This truth of uncertainty (which itself at once resembles a paradox) must be communicated to the individual enrolling in the clinical trial, in a kind, compassionate, trustworthy, and humble manner. Such an experience, or ones like it, can be common to clinicians, nurses, study coordinators, ethicists, chaplains, hospital administrators, and many other professionals involved in the patient's pathway of care in medicine or science. Science is implicated, because the doer or learner of science must maintain intellectual curiosity and a commitment to seeking and reporting only the truth, with the knowledge that others in science and medicine will depend on this truth, which can ultimately have tremendous implications for the patient. Thus, the truth of scientific observations and concepts must always be preserved.

Importantly, the truth in science can appear to evolve, as new discoveries (which are direct outcomes of creativity) shed new light on mechanisms and pathophysiology. Yet, it is not the underlying truth itself that is evolving. It is the perception, interpretation, or subjective bidirectional reflection of the objective data that evolves as new data unfold. By way of illustration, the truth of scientific and biomathematical concepts based on perturbation and homeostasis can be considered analogous to social concepts of harmony and balance.

Scientific Birth

Why do we oscillate, vacillate, fluctuate?
Why aren't we constant and stable?
Why do we question and cast our curiosity
Out into the vast oceans of time and space and science?
Why do we observe and characterize and categorize?
Why do we stand in faith?
Why do we wander around in a cloud,
Not knowing when we will breakthrough?
It is because that oscillation, vacillation, and fluctuation
Leads to new birth.

When a birthing mom pushes,
She breathes and pushes some more,
She relaxes for an ever so slight second,
Then pushes some more.

And that final push gives birth
To a thought, an idea, a bundle,
A new finding, a new observation, a baby.
A baby that is introduced to the world
For the first time.
That may bear resemblance to its parents
And that testifies to the truth
Of its source.

In this illustration, molecules interact with each other in much the same way that humans do, albeit at a much lower order of thought. Molecules dance and kiss and hug and shake hands. They swim past each other and run alongside one another. Not just molecules but characteristics of the molecules. Their quantity and sensitivity and responsiveness and specificity can be modulated physiologically and pathophysiologically in a coordinated fashion, just as choreographed dance can. Molecular assembly in a series of steps intrinsic to a cell can also resemble a choreographed dance, or a sequence of scenes in a movie, except that the movie repeats itself over and over. This could be akin to going to see the same movie many times but each time gaining a different perspective from the same picture—a perspective that rests in homeostasis after each perturbation.

The truth of scientific and pathophysiologic concepts is not always easy to discover but often derives from tremendous effort and anticipation of breakthrough that yield the drive to push toward it. Suitably, the poem "Scientific Birth" alludes to this effort and persistence in pursuit of discovering truth (see Sidebar: Scientific Birth). This pursuit of a particular answer to a question can sometimes lead to discovery of an unrelated and important truth (as was the case for a scientific study example from Brown et al[47]). This phenomenon captures what has been referred to as the cloud (Appendix B. Glossary[a]).[48] The scientist finding the discovery in the cloud can result in the development and mastery of a (frequently novel) niche. A poem can reflect or take the shape of scientific or biologic objects. Each stanza of the science poem "Scientific Birth" illustrates a different shape with the same structure: A head (most lines of the stanza) that culminates in a narrower neck (last line of the stanza). The stanza demonstrates

the varying radii and lengths of cerebellar Purkinje nerve spines (or protrusions) of different geometries.[42]

It behooves us to consider that as we seek to discover and retell the truth from our own subjective perspective, our very humanism itself—with our biases, assumptions, and value judgments—has the potential to compromise or undermine our relaying of the truth.[49,50] Our poems and other media for creative expression are instruments that can produce attitudes in recipients of our work, who may openly trust our poems and other creative expressions as they might frankly trust a friend, and whose assent we win through constructing convincing voices as creatively distinctive speakers that move and challenge them.[49] We must guard against injustice to them, which in the end would be injustice to ourselves, our colleagues, our patients, our clients, society at-large, and science and medicine at their purest.

How Will I Dance?

Now that you've taken away my balance
How will I prance?

Now with this unsteadiness,
How will I find happiness?

Now with this slur
How will my voice be heard?

When my legs fail,
Who will listen to my wail?

When I can't keep my gaze,
Who will help me see through the haze?

When this ataxia threatens to take control,
Will it take a toll

On me?

Perhaps it will affect the flesh of my body,
But it will not deter what's inside of me.

Perhaps it will take away my voice,
But it will not remove my choice

To decide
How to abide.

Not in fear or anticipation,
But in the knowledge of my dedication.

To the essence of who I am,
To the essence of what I can

Achieve.

Although ataxia will try to rain on my parade,
My will and gusto will form a motorcade,
A barricade,
A barrier.

My spirit will dance
My heart will dance
My mind will dance

And by golly,
My voice will dance.

My voice is within.

The dance is within.

POETIC SCIENCE: DIFFERENT PERSPECTIVES

The pure truth in nature can be approached from different angles. The eye of each beholder will determine the slant with which truth is interpreted and, moreover, appreciated. This underscores the philosophy of bidirectional reflection between 1) the inquisitor or the learner and 2) science or medicine. This can be captured in various forms of creative expression in poetic science; inasmuch as the process is objective, it is also subjective.[48]

Perhaps then, poetry and science could be regarded as interdependent means of learning more about the world (see Appendix G. Poetic Science Paraphrased[a]). Although the sciences and poetry are often perceived as worlds apart, they are alike in many ways.[51] Scientists and poets regard the world with wonder and provide records as witnesses, in such a way that an observation could easily become a poem.[51] Furthermore, poets investigate the sciences, scientists of various sorts are tempted by verse, and poetry and science occasionally get together for tea, like old friends.[52] It may be that whereas a scientist reflects on the world by looking outward with prediction, the poet reflects inward in a continuous intimate motion,[53] both producing their version of truth telling. Consider, for example, that the scientist and the poet stand on 2 sides of a revolving door. Each side gives a different perspective on the world around the singular door constantly yielding to momentum. Nevertheless, both the scientist (or physician) and the poet (or other kind of artist) seek to make a difference[31] and to leave a mark or memento where they have trod. The scientist hopes that this is some elucidation of the underpinning that explains the hidden mysteries inside the human body, human behavior, or nature. The artist hopes that it is a profound depiction and encapsulation of the overlying hues that permeate the external world. Thus, the scientist artist or poetic scientist can wed 2 different perspectives from both sides of the revolving door, in appreciation of both the objective and the subjective. In this way, creative expression of medicine and science can empower the imagination beyond what is already known or understood.[53] The sciences and medicine continue to evolve and provide new worlds for poetry to explore, leading to metaphorical fusion.[54] Accordingly, numerous scientist artists have adopted titles such as "Poetic Science" or "Poetry of Science" for their creative collections.

POETIC SCIENCE: MOTION FOR MOTIVATION

Poetic science may help physicians understand the plight of our patients and shape motivation for pressing on in learning and innovation. For example, the poem "How Will I Dance?" (see Sidebar: How Will I Dance?) goes beyond the objective aspects of the science and medicine of ataxia (a medical disorder affecting movement) to the subjective aspects of the illness.[55] Such a poem can have an impact on not only clinicians but also on patients. By illustration, several months after receiving a diagnosis of ataxia, a patient received this poem as a holiday gift from her sister.[56] The patient and her extended family were brought to tears and felt it was a perfect gift. Consequently, writing and sharing such pieces can have an impact on clinicians and other learners, as well as patients. Such impact may help learners understand far-reaching influences of molecules and biological processes involved in biomathematical and wet-laboratory experiments.

VORACIOUS EXHORTATION

As in "How Will I Dance?" (see Sidebar: How Will I Dance?), the poem "Just One More Step" (see Sidebar: Just One More

Step) encourages the recipient, no matter how difficult a task may seem, to grab the challenge by the horns and resolve to take just one more step.[57] This continuous resolution leads to triumph that one must define for oneself. The need for such resolve resonates with countless persons in science and medicine, including the poem's author. To illustrate, as one matures in the sciences or medicine, one also learns a lot about the process of doing research. One learns how to fail without considering oneself a failure. Yet, one comes to understand that experiments will fail, that in some sense, experiments should be expected to fail. When experiments finally work, a truth may be discovered that, although not the original pursuit, is worth publishing. In this process, one presents ideas to colleagues, advisors, or mentors and pays keen attention to feedback. Somewhere in the midst of cooperative brainstorming, concordant ideas will dance in harmony and emergence.

Importantly, scholars of science and medicine should recognize that experiments and plans do not define one's identity. Every learner should recognize that s/he is more than a test tube, a pipette, a keyboard, a pen, a stethoscope, a scalpel, and the back of an envelope, combined. Then the intellect and creative soul can freely engage in the Argentinean tango or any other sort of dance that celebrates two. Such a choreographed outcome can result from many previously unchoreographed steps. With each challenge, difficulty, struggle, or roadblock, one must resolve "just as I could choose to stop, I could instead choose to step ... ," as exhorted in the poem "Just One More Step"[57] (see Sidebar: Just One More Step). On reading the poem, one midcareer scientist and one midcareer physician were brought to tears, thinking about their own struggles and those of their trainees. One young patient with dysfunctional peripheral nerves and limited sensation and motor function in his legs felt "Just One More Step" hit home for him in a practical way. Stories like these inspire the poem's author to continue to voraciously read scientific and medical articles and textbooks, and thoughtfully write creative manuscripts, essays, and poems, to continuously build capacity for impact in poetic science.

POETIC SCIENCE CAN EMBODY SCIENCE AND MEDICINE

A few novel examples are shared here in the forms of poems: "I Love The Spine Neck" (see Appendix C. I Love the Spine Neck[a] and Appendix I. I Love The Spine Neck Diagram[a]), "A Delicate Dance" (see Appendix D. A Delicate Dance and Appendix J. A Delicate Dance Diagram[a]), and "Ataxic MatchMaker" (see Appendix E. Ataxic MatchMaker and Appendix K. Ataxic MatchMaker Diagram[a]). These poems illustrate creative expression in the disciplines of medicine, neurobiology, and cell biology and are appropriate for all age levels, particularly undergraduate and graduate students. Learning concepts include ataxia (a failure of muscle coordination),[58] form and function of the dendritic spine (a microscopic component of nerve structure), geometric diversity of the spine neck (the neck connects the spine, a protrusion from a branch of the nerve cell, to the rest of the nerve cell), characteristics such as concentration or sensitivity to activation of the IP3 receptor type 1 (an important receptor for calcium signals in nerve cells), calcium signal inputs and outputs, and homeostasis (in response to perturbations in nerve cells) (see Appendix K. Constructs of Poetic Science and STEAM[a]). Several creative works have been crafted to embody these concepts (see Appendix C. I Love the Spine Neck,[a] Appendix D. A Delicate Dance,[a] and Appendix E. Ataxic MatchMaker[a]), and referenced in this section. Because poetic science items should always be intimately related to findings in nature, science, and medicine, the example poems included here are closely linked to published articles in journals, newsletters, magazines, and books about science or medicine[42,47,57,58-71] (see Appendix M. Poetic Science: STEAM Approach[a]).

The poem "I Love the Spine Neck" is based on thoughts about the cerebellum in the posterior brain that coordinates movement (see Appendix C. I Love the Spine Neck[a]). This occurs because of biochemical signals involving calcium, IP3, and phosphoinositol bisphosphate (PIP2) in cerebellar Purkinje neurons. The poem is also based on thoughts about systems biology and computational neuroscience or mathematical neuroscience, which involve

Just One More Step

I could give in to the challenge before me
Or yet I could give out.
Alternatively, I could give all.

All I have in me
All I have left
To step.

I could stay in this position
I'm sure I could find justification.

But just as I could choose to stop …
I could instead choose to step.

If I could take
Just one more step,
I know I will be alright.
I know I won't be back at the start.
I know this with all my heart.

If I could take
Just one more step,
I will be closer to the finish line,
Where an earned yet gracious victory will be mine.

If I could step
I know I'll make it
I know my dreams will come true.

I must keep on stepping
Whether with my pen or my finger
With my voice or my pointer
With my legs or my walker
With my feet or my wheeler.

With a clear gaze,
Or through the haze,
With my muscles cooperating
Or with me overcoming,
I must just step.

With the software freezing
Or running smoothly,
Running out of memory
Or making things easy,
I must step.

With the tears and the fears,
Literally and figuratively,
Respectively,
I must just step.

Until I achieve my goal
And until the race is o'er
I must keep on stepping.

No matter what stage,
I must still take
One more step.

using mathematics and various tools in biotechnology (such as 3-dimensional reconstruction of the cerebellar Purkinje nerve cell) to study the brain[42,66,72,73] (see Appendix H. The Spine Neck diagram[a]). The poem focuses on the contributions of the spine and its neck to calcium measurements in the "wet lab" and to biomathematical experiments.[65,66]

The poem "A Delicate Dance" is more technical in its descriptions[65] and portrays movement functions disrupted in ataxia, as well as their importance for the affected individual (see Appendix D. A Delicate Dance[a] and Appendix J. A Delicate Dance diagram[a]). It draws on inspiration from the National Ataxia Foundation (www.ataxia.org) and alludes to potential therapies such as ICpeptide, a protein fragment that binds the IP3 receptor to modulate calcium levels. These therapeutic pathways also were interrogated through biomathematical modeling.[65]

The poem "Ataxic MatchMaker" (see Appendix E. Ataxic MatchMaker[a]) is a follow-up to "A Delicate Dance." It is based on biomathematical modeling of scientific concepts of perturbation and compensation mediated by calcium-binding proteins (parvalbumin and calbindin),[65] as well as social concepts of harmony and homeostasis (see Appendix I. Ataxic MatchMaker diagram[a]). It also draws on results of several wet-laboratory experiments from other groups.[62-64,67-71,74,75] It presents the concepts of function, dysfunction, crossroads, and passing the torch to the next generation.

POETIC SCIENCE: CREATIVE ENGAGEMENT

Engaging Clinicians and Scientists in Poetic Science

Aesthetic engagement, such as response to visual art, associates with openness and interest in novelty.[76] Such novelty can facilitate learning and discovery in medicine and the sciences. Novelty and curiosity can also lead to integrative aesthetics, in which fusion of art, scenery, lighting, color, music, poetry, drama, performance, touch, and perfume are incorporated to heighten sensation and intellectual speculation.[31]

Such intermingling of artistic and philosophical disciplines can be thought of as *counterpoint,*[31] which is an intriguing artistic term. *Counterpoint* refers to the combination of 2 or more elements that are at the same time complementary and contrasting to each other, usually in music or other visual, fine, or performing art forms. Examples can include adding harmonies to melodies in music, in such a way that the 2 elements contrast each other and maintain their own independent character. In a sense, the 2 elements enhance each other to yield an emergent and beautiful outcome. Similarly, intermingling of creative expression and medicine or science for the sake of novelty, curiosity, and learning could also be termed counterpoint as a process of bidirectional reflection to yield a pleasantly informative outcome (Figure 1).

Thus, poetic science may be useful for transdisciplinary sharing, education, and learning in science, medicine, and the arts. Additionally, poetic science can highlight the human component of science and medicine. Such discourse could potentially also be appreciated by medical and graduate students, nurses, chaplains, ethicists, hospital administrators, and so on.

Various other authors, tutors, and learners have produced creative expression of science and medicine.[5,11-14] There are multiple resources available for engaging clinicians and scientists in poetic science. For example, a brief guide illustrates how to write a 55-word story packed with impact while maintaining simplicity.[15] Other examples describe taking students to examine painted portraits to improve their observational skills,[16] small-group training using photography or art plus dance to develop pattern recognition,[17] encouraging learners in exercises of reading and writing literary works to embrace news ways of revealing and telling truth,[18] offering the option of submitting novel creative media to explore learning through visual art or music as a way of reflecting[19] (Figure 1), or bringing diverse scientists and poets together for mutual inspiration leading to a balanced mix of scientific verse and prose.[20] Resources also exist for creative arts teaching and practice in general.[1,77-79] Many use pretest and posttest questions to evaluate learning (see potential suggestions in Appendix N. A Poetic Science Approach to Education[a]). Such materials could be iteratively developed further by practitioners and learners after literature review, drawing on prior publications on creative expression in science, technology, engineering, arts, and mathematics/medicine (STEAM) education[5,10-13,21-27,80] (see Appendix M[a]).

Potential Approach for Social Media

To innovatively expand the impact of poetic science, the digital portions of poetic science could be further applied to individuals on Facebook and Twitter, or other forms of social media.

Whereas electronic paths may be traced via Facebook, Twitter is thought to offer more anonymity regarding electronic links pursued by individuals on Twitter as opposed to following the same links from Facebook. Thus, applying digital poetic science on Twitter may potentially suit an exempt institutional review board application for educational purposes. Tweets could mention trending hashtags related to poetry, science, creativity, humanities, digital humanities, and medicine. For a neurobiology audience, trending neuroscience and neurology hashtags (eg, #Neurology, #Neurologist, and #Neuroscience at the time of this publication), as well as influencers on Twitter (individuals well positioned on Twitter to reach a broad audience once one connects with them) could be mentioned in the tweets about the poetic science project.

To maximize benefit from the study, the study designer should undertake a clear evaluation process, such as one along the lines of the following. Very brief information about the poetic science project and the link to a simple anonymous multiple-choice pretest (eg, hosted on www.surveymonkey.com; Palo Alto, CA) could be posted on Twitter with mentions of trending hashtags and influencers. The pre-pretest could then direct individuals to additional information and links for the Poetic Science STEAM Seminar Video Series located at http://bit.ly/2i1jg2D and http://bit.ly/2DKXElq (audio version: http://bit.ly/2GoJfZV) and the Poetic Science STEAM PowerPoint Slides located at http://bit.ly/2fFX4dw, http://bit.ly/2i0mN0Z, and http://bit.ly/2vDuGww. Individuals could be invited to leave or send in testimonials after interacting with these resources. These could all then link to an identical multiple-choice posttest (eg,

hosted on www.surveymonkey.com) with a request for individuals to take the posttest, whether or not they completed the pretest. At the end of the posttest, individuals could again be offered the opportunity to leave comments and testimonials in a free-form text box, if desired. The results could be collated and displayed, presented, or even submitted for publication, with the goal of furthering the impact of poetic science. ❖

[a] Available from: www.thepermanentejournal.org/files/2018/17-177-Appendix.pdf/.

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

Acknowledgments

The author is grateful to Sherida Powell, PhD, formerly of George Washington University in Washington, DC, for conversation leading to the first half of the poem "Coincident Incident"; and to all who have laid eyes on and commented on Poetic Science.

Kathleen Louden, ELS, of Louden Health Communications provided editorial assistance.

How to Cite this Article

Brown S-A. Poetic science: Bidirectional reflection in science and medicine. Perm J 2019;23:17-177. DOI: https://doi.org/10.7812/TPP/17-177

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