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Interdisciplinarity is key to a well-rounded scholar. The exchange of ideas, tools and methodologies across fields facilitates a scholar's growth beyond the bounds of their singular area of expertise, allowing room for creativity and inspiration to flourish. As a result, the Jefferson Journal of Science and Culture was founded on the belief that the cross-pollination of various disciplines is a crucial factor for innovation, creativity, and the advancement of scholarship. To facilitate such an exchange, this annual journal is dedicated to publishing articles from a multitude of domains that employ interdisciplinary approaches or teams, all concentrated around a central topic of interest for each issue. In this way, the particular topic may be viewed in a fresh light, promoting new perspectives and the broadening of one's intellect. "The real voyage of discovery consists not in seeking new lands but in seeing with new eyes." – Marcel Proust

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Editors' Note

Dear Readers,

Scholars have unique understandings of the nuance, complexity, and beauty within their disciplines. All disciplines engage with understandings and perceptions of beauty, although they may vary in their objectivity, subject matter, or level of abstraction. What is beautiful, how to define beauty, and what is the role of aesthetics in understanding are all fundamental questions that cross disciplines and cultures. For the arts, humanities and social sciences, beauty may lie in physical works of art, cultural preferences, historical trends, or philosophical understanding; in mathematics and engineering, beauty may be present in data, equations, or architecture; for the natural sciences, beauty may be hiding in the physical world and its myriad properties. It is the goal of this issue of the Jefferson Journal of Science and Culture to present a series of scholarly articles exemplifying the variety of perceptions of beauty and aesthetics present in scholarship today. Articles were selected based on their contribution to their respective fields, interdisciplinary impact, and ability to relate all presented information to a broader audience.

Sincerely,

Josephine Lamp

Josephine Lamp - Editor-in-Chief

Robert Moulder Jr.

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Jefferson Scholars Foundation

The Aesthetics of Interpersonal Attunement in Spiritual Care

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This article explores how storytelling plays an integral role in interpersonal attunement, attachment, and spiritual caregiving. An interpersonal style of attuning to the experiences of others constitutes an ethical aesthetic of resonant harmonizing between the bodies, nervous systems, and minds of caregivers and patients. Neurobiological research has provided empirical scaffolding to rationally understand how attuned relations regulate the nervous systems of the relating persons. Compassionate caregiving in clinical chaplaincy practices relies on the cultivation of self-regulation capacities through meditation practices on the part of caregivers. Compassionate caregivers then use their emotional equilibrium and empathic insights to open an interpersonal space for receiving the stories of patients, families, and other caregivers in clinical settings. Self-regulation and self-transcendence depend on the empathic understanding between persons and social groups that counteract the harms endemic to many late modern social institutions in which systemic violence often takes place. This article concludes that attuned spiritual caregiving is an appropriate social response to complex trauma and social suffering in the late modern context.

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire,
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate,
To say that for destruction ice
Is also great
And would suffice.
—Robert Frost

As early as I can remember, I loved the play of images, emotions, and thoughts in poetry and storytelling. As a young man in high school and college, reading and discussing literature so appealed to me that I often neglected my other studies so that I could read books that recounted imaginary events, people, and places. As I matured into a scholar and spiritual caregiver, I found myself returning again and again to the power of stories for reasons I could not always explicitly relate to others. I studied the anthropology of storytelling intensely at seminary. In my theological education and in my doctoral program, I learned to deconstruct narrative structures and to show narrative contingency. I impressed myself with my ability to suspect the untruths or untold truths that narratives masked, seeing the telling of narratives as but one more game of truth in an array of knowledge construction. All along, a strong gut sense remained inside that stories have meanings beyond what we learn from their contents, deconstructions, or social functions.

I intuited that stories grow as social organisms that bind together and break apart communities, worlds, and worldviews. Recent social and political developments, of the tragic and noble variety, have not convinced me otherwise. Responsible and attuned caregiving requires I resonate with my internal world as the basis for understanding others. So, I begin with this autobiographical aside in order to frame an argument about the value and limitations of stories in the practice of spiritual care. Spiritual care is a discipline that informs the practice of hospital chaplaincy. It combines religious practices with psychotherapy, attempting to make meaning out of illness experiences. Hospital chaplains attend to the needs for comfort, companionship, and meaning-making of patients, families, and caregivers who confront health crises. Spiritual care has captivated my scholarly and practical attention for nearly a decade because I see in it a dignified effort to humanize contemporary medical institutions.

In this article, I will make an argument for the value of deeply listening to stories, and about the beautiful reciprocity that emerges between a listener and teller. I will warn against the fearful symmetry that prevails when threat characterizes human interaction. I will describe how stories can integrate the experience of trauma survivors after calm and peace return to life. The positions I articulate here are informed by my original love of narratives put into dialogue with threads of scholarship found in the disciplines of interpersonal neurobiology, attachment theory, and integrative and attuned storytelling. Looking at storytelling from the interaction of these fields of study leads me to an appreciation for the neurobiological prerequisites for empathically sharing stories and the value of storytelling as a social mode of integrative healing. My broad point is that human interaction exhibits an ethical aesthetics of mutuality, which can take sublime and terrible forms depending on the state of the

bodies and minds that encounter each other.

Why is compassionate care so necessary for healing?

Besides the fact that compassionate care viscerally feels like the right response to mobilize when tending to persons contending with an illness, it activates bodily healing. Isolated persons in a lonely hospital room suffer intensely from the bodily consequences of being removed from the social context in which they feel physical, social, and emotional support. Consider the following scene. A woman named Clara wakes up in a dark room on a bed with stiff linens, clothed in a rough gown, with her torso raised slightly above her legs. She hears the slow and steady beat of a heart monitor. The sounds of people hurrying to and fro in the hallway just outside her room slip below the bottom of her door. She is not entirely sure where she is at first.

Day breaks shortly thereafter and a nurse comes into what Clara realizes is her hospital room. The nurse asks Clara questions to see if she knows her own identity. Clara does remember her name, age, work, and family. She is unsure of the date, and some of the details of the last few days are unclear to her. She remembers a searing pain in her left arm that she felt at work earlier. "That must have been yesterday," Clara thinks to herself. Her nurse comes and goes every hour, makes eye contact, talks to her for a few minutes, and then spends her time charting on the room's laptop. The nurse's eyes are kind but the moment of connection is brief. Clara feels scared.

She also feels confused, and by the end of the day she is wondering where her family is. She starts to feel an uneasy tightness in her lower abdomen. She starts to want to talk with someone to pass the time. She grows ever more worried about what happened and what that means to her future. The nurse said that Clara suffered from a heart attack. Clara is shocked and wonders what changes she will need to make in her life to avoid any future cardiac events.

Neurophysiological and immune system research suggests that an overly active sympathetic nervous system removes the body from the restorative state necessary for healing (Porges, 2017; Van der Kolk, 2015). The sympathetic nervous system is associated with arousal, anxiety, fear, stress hormone release, and fight or flight states. Its counterpart is the parasympathetic nervous system, which dampens arousal states. Human beings most readily activate parasympathetic response through social engagement, including storytelling, grooming, singing, and gentle physical touch. Spiritual caregivers provide the kind of receptive presence that dampens physiological arousal, helping patients relax through social engagement and talk. The need for spaces of open and trusting communication is not confined merely to medical institutions. Imagine the social isolation in prison systems, and one can intuitively see the validity of the argument for more and better trained chaplains in many late modern institutions to assuage human suffering.

The application of chaplaincy craft applies in social institutions and movements beyond the traditional places where chaplaincy has emerged. Chaplaincy serves the needs of persons facing questions of meaning and integrity outside of the military, prison, and hospital settings in which it historically arose. Chaplain Jinji Willingham, a graduate of Upaya Zen Center's chaplaincy training program, suggested chaplaincy will become the front line spiritual therapy in the next generation. Working with the notion of interpersonal repair, Willingham argues that chaplains counteract the primary wounding that takes place so often in social contexts when attuned relationships are absent or strained.[1] Chaplains provide a body-nervous system-mind capable of attuning. This means chaplains can mirror the emotions they see in others while adding compassionate response in such a way as to provide means for interpersonal healing that quenches negative reciprocity. The leadership of Upaya, one of the foremost training programs for Zen Buddhist chaplains in the US, have also provided the social scientific and neurobiological scaffolding that supports claims about contemplative chaplains' effectiveness in interpersonal neurobiological terms. Chaplains and other medical practitioners who periodically gather for intensive retreats at Upaya at the foot of the Sangre de Christo Mountains on the north side of Santa Fe endeavor to cultivate a sense of self that acts compassionately when confronted with suffering.

What does adaptive interpersonal symmetry look like in compassionate caregiving?

The practice of a helping profession like chaplaincy, clinical psychology, or counseling pivots on the exchange of stories. Engaging the social system necessary for such an exchange depends on all the parties involved achieving cognitive and emotional equilibrium. We can see this interpersonal dynamic at work in the ways in which caregivers reflect on how they, in relationship with patients, co-regulated the affective energies that all parties perceive and manage in clinical caregiving encounters. Co-regulation means that two or more bodies and extended nervous systems become partners in monitoring and modifying energetic flows in the context of relationship. One clinical chaplain describes in a particularly salient way how the process of compassionate listening requires properly attuning to herself. Naomi Saks is a Buddhist chaplain who works at the University of California San Francisco teaching hospital. Saks describes her ability to pay attention to stories she hears patients relate about their experience as a skillful awareness that resides in her body. Drawing on her training at Spirit Rock, a Northern Californian Buddhist community, Saks calls this intention to "soften"

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[1] Willingham, Jinji: Personal Interview, May 5, 2018

herself to the moment and what happens in it "love."[2] When she roots in her own bodily experience and softens to what she finds, Saks provides herself with the means by which to attune to the presence of the patients, families, and other staff members she serves. She feels them inside her own bodily awareness.

When she is present to the full array of sensation, cognition, and emotion activated in her body and mind, she can be present to the sensation, cognition, and emotion she intuits in the bodies and minds of others. Saks practices a form of open awareness meditation practice each day. Her style of contemplative practice moves beyond any confineable location because she has internalized the capacity to be present no matter the circumstances of distress and hardship she finds within or without. She has cultivated this stance toward experience to such a degree that it has become intrinsic to her body, nervous system, and mind. It has become a character trait, and not just a temporary state of mind. "In my being," she continues, "I am present to what is arising moment by moment. I can feel that person I am visiting in a hospital room in my body-mind in the moment I am there with them if I am attentive."[3] Saks claims that when the patient's presence is available to her in her mind-body, she can better serve the patient because she can feel them and intuit their inner world. In her understanding of her practice, this awareness of the patients' experience in her sense of her own interior life is the index to point patients toward "being and allowing their experience to happen."[4] As Saks attunes to herself, she opens her awareness up to attune to others in her perception of the interpersonal field of being.[5] Exteroception—perception of the external sensory world—and interoception—perception of the inner visceral state—are intimately connected in her experience. That is, the identity of caregiver and patient can only emerge in the in-between spaces of relationship.

In this way, stories come to life in the bodily presence of the spiritual caregiver, which is like a theater screen displayed with the stories, thoughts, and affects of the people who talk with her. Her inner world resonates with the other's thoughts, feelings, and sensations. Saks goes on to offer her own observation about how early childhood experience makes accessing awareness of bodily states, sensations, and emotions difficult for many people in late modern US society. She proposes that our society makes experiencing emotions related to fear responses—anger, fear, hatred, contraction—unpalatable and unmentionable in everyday conversation. She then remarks, "I am not teaching people I visit anything that is beyond them or new, but I am helping them find the truth. I am helping them find a way to come home."[6] By finding a receptive caregiver, persons who are confronting the hardships of illness may have the ability to connect with themselves at a deeper level. They may be able to integrate more of their experiences.

In medical anthropologist Kleinman (1988)'s language

they discover together "the moral lesson that illness teaches" (Kleinman, 1988). Suffering is ubiquitous, but it does not have the final say in what meaning human communities living in solidarity find in its face. In a reciprocal way, chaplains and patients care for and tend to each other. They can rebalance each other and provide each other with a pathway to self-transcendence. The aesthetic symmetry of care draws together two or more bodies and minds into one social organism that transcends any one member alone. Patients and chaplains are reciprocal caregivers that become one body entwined in the compassionate care of embodied awareness for the pain and suffering of imperiled or damaged human tissue in either organism.

The moral lesson of illness insists that pain and suffering are the inevitable precursors to self-transformation. Self-transformation necessarily entails some degree of self-transcendence. In this sense coming home means finding a way to recover knowledge of one's own body and at the same time to extend beyond one's bodily limits. Illness invites a return to the body as the primordial location of human dwelling,[7] while also showing how to cross over into another domain of experience unlimited by the body. In the same instant as one knows one's interoceptive experience, one is shown a passage for crossing over beyond the limits of one's body. Serving another as a guide home also gives the servant-guide the reciprocal gift of knowing the way home. "I am

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[2] Saks, Naomi. Personal Interview, February 28, 2018

[3] Saks, Naomi. Personal Interview, February 28, 2018

[4] Saks, Naomi. Personal Interview, February 28, 2018

[5] The "intersubjective field of being" was a phrase repeatedly used by Fleet Maull in a training on compassion and wisdom he conducted from August 8, 2018 to August 11, 2018 at Upaya Zen Center. It originates with Maull's deep engagement with Daniel Siegel's work. That being said, numerous anthropological authors speak of the field of intersubjective relations including Fabian (2014), Kleinman (1988, 2007) and Jackson (2002). One brief quote from Kleinman (1988) points to how an emphasis on intersubjective experience leads to greater attention to the experience of suffering in medicine: "Ethnography, biography, history, and psychotherapy—these are the appropriate research methods to create knowledge about the personal world of suffering. These enable us to grasp, behind the simple sounds of bodily pain and psychiatric symptoms, the complex inner language of hurt, desperation, and moral pain (and also triumph) of living an illness" (Kleinman, 1988).

[6] Saks, Naomi. Personal Interview, February 28, 2018

[7] See Tweed (2009). Tweed (2009) insists on the religious activity associated with dwelling. Defining his usage of the term, he writes: "Dwelling, as I use the term, involves three overlapping processes: mapping, building, and inhabiting. It refers to the confluence of organic-cultural flows that allows devotees to map, build, and inhabit worlds. It is homemaking. In other words, as clusters of dwelling practices, religions orient individuals and groups in time and space, transform the natural environment, and allow devotees to inhabit the worlds they construct" (Tweed, 2009).

helping them, and I am helping myself, to come home and to soften when I am reactive and scared, when they are reactive and scared."[8] In providing orientation to a patient looking for a route back to her dwelling in the body, the clinical chaplain is gathering maps to orient her own homecoming.

Spiritual caregiving practices that find their ground in contemplation hinge on the social and emotional resonance between and within human beings. This means that assisting in the repair of another's relationship with herself or the imprint of her traumatic experience in her body also heals the chaplain providing the assistance. Saks's caregiving mode suggests that in doing mindfulness practice, the chaplain simultaneously improves her relationships with external actors—interpersonal attunement— and with herself internally—internal attunement (Siegel, 2011). She befriends herself, so that she can befriend others. Being a friend to herself and others also means accepting what she does not like.

What kind of body does the social engagement mediated through storytelling assume? What kind of body is capable of resonating with the heart of stories?

Taking care in stories, as Naomi Saks does rather skillfully, teaches a way to be in attuned relationship with others. It draws on all the learning that human beings discover when they take the time to gain an awareness of the complicated, beautiful, and fraught nature of intersubjective experience. Stories powerfully indicate the health of their narrators because they perform a type of healing that draws together the fragments of memory that traumatic events imprint in the body. These traumatic imprints tend to dissociate body and mind. Indeed "the body keeps the score," as the research of trauma theorist and psychiatrist Van der Kolk (2015) recently asserted so forcefully.[9]. The body keeps track of all the slings and arrows one suffers, even when the mind ignores or neglects them. Van der Kolk (2015)'s perspective resonates with those of anthropologists like Kleinman (2000) and Jackson (2002) on how social and interpersonal violence inflicts somatic wounds that alter human experience in deleterious ways. Talking about traumatic events does enable survivors to reintegrate their experiences but complex trauma poses problems to integration and healing that stories alone cannot solve.

Solving these problems essential for our time, a time when nationalist tribalism threatens to plunge our cities, states, and nation into a state of social and political disintegration. We need healing in interpersonal relationships but also in social institutions. We need a cadre of well-trained spiritual caregivers who embody the bodhisattva, that is never disparaging, unswerving, positive regard for all sentient beings. This kind of positive regard, practiced by the likes of Martin Luther King Jr. or Mahatma Gandhi or Jesus Christ or Shakyamuni Buddha, refuses to hate. As the Lotus Sutra narrates, Upaya's Joshin Byrnes reminds us, the bodhisattva's constant reply to all is: "I love you" (Byrnes & Quennell, 2019). As another famous bodhisattva expressed it so succinctly: "Those who will falsely accuse me, and others who will do me harm, and others still who will degrade me, may they all share in Awakening." [10] Limitless positive regard for others is the bedrock for attuned relationships. It is a boundless abode that is deeper and more loving than stories or any other artifact of worded techniques.

A social context in which we trade stories without limiting who gets to tell them, without privileging certain types of stories, requires the development of certain neurophysiological states. One of the most exciting elements of practicing a helping profession in the contemporary moment is the explosion of data and theories published in the last thirty years that objectively explore the interior of human experience with greater nuance and clarity. For example, the last three decades have witnessed an intensification of the search to link subjective experiences of the mind in relation to maps of activated neurological correlates. The studies on the nature of nervous system correlates to human consciousness and experience are so diverse that it is rather hard to characterize their import in one or two paradigmatic shifts.

For my purposes here, I will point to one particular paradigm shift that places greater awareness on the nature of bottom-up processing. Neuroscientist and Zen practitioner Austin James (2010) describes bottom-up processing as the stance of open awareness that meditators take when they activate temporal-occipital lobe pathways of attention. In this form of open monitoring meditation,[11] which is common to all schools of meditative practice in Buddhism, bare awareness is intuitive, insightful, and choiceless.[12] It foregrounds the experience of others. Social scientists and philosophers

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[8]Saks, Naomi. Personal Interview, February 28, 2018

[9]Van der Kolk (2015), especially 89-106

[10]Śāntideva (1995), 21. Śāntideva wrote these verses in North India sometime between 685 and 763 CE.

[11]See Vago and David (2012), 13.

[12]Austin James (2010) describes bare awareness as the mode of consciousness that corresponds to a link between the temporal lobe, occipital lobe, and fusiform gyrus as they connect to the right prefrontal cortex structures associated with attention. Bare awareness focuses on the experiences of others in the surrounding environment. It enables a meditator to decenter. To achieve a state of unification with the outside world also requires dampening of the thalamus through GABA receptors of the dorsal thalamus, which quiets the limbic drives by closing the gate between the neocortex and the limbic system (amygdala, hippocampus, hypothalamus, and their associated supporting structures). GABA is the inhibitor responsible for quieting or deactivating neurological circuits, which can dampen fear responses in the amygdala. Austin James (2010) argues that kensho (unitive experience) would achieve the activation of the networks associated with other-awareness and the dampening of fear responses and egocentric circuits.

have long argued for ways that moral codes, autobiographical memory, conceptual regimes, and implicit assumptions like embodied schema constrain perception and sensation. This is what is often called top-down processing. To research bottom-up processing is to study how conceptual, moral, or schematic reasoning emerges from perceptual and affective experience and is encoded in memory. Contemporary empirical data, inconclusive yet persuasive, suggests that bottom-up types of processes like the open monitoring aspects of mindfulness meditation have great therapeutic value (Van der Kolk, 2015).

Mindfulness provides meditators space in which to step away from habitual thoughts, feelings, and perceptions in order to decenter. As meditators become progressively absorbed, they become the vessel of open awareness that attends to others. Via deepening mindfulness practice, meditators open their consciousness to novel perceptions and sensations that free their sense of self from habituated maladaptive thoughts and emotions. This is of great value to the practice of spiritual care in biomedical institutions in the US, which have toggled between the work of healing and the work of self-transcendence from its very beginning during the early twentieth century. Freeing one's sense of self from harmful thinking and feeling is of great therapeutic value, and therapeutic value is an important consideration when trying to heal wounded hearts and minds.

Freed mind-bodies find the means to transcend self-interest. Transcendent moments inspire healing, and healing is one of the essential consequences of hearing each other's stories. In a contrary vein, a fearful symmetry emerges in interpersonal relationships and social structures when emotional disequilibrium reigns. Patients and chaplains cannot arrive at the state of bodily peace that deeply listening to another human being requires by thinking themselves into that space. They need to attend to regaining balance in their sensational affective organism to find connection with others that takes them outside of their concern for themselves. For example, Van der Kolk (2015) writes of how drama therapy has helped to heal traumatized youth. "Mirroring loosens" preoccupations "about what other people think of them," he says, "and helps them attune viscerally, not cognitively, to someone else's experience" (Van der Kolk, 2015). Freed from self-interested thought and attending to others, youth recovering from trauma feel the inner world of their trusted group members which frees them from their self-preoccupations.

Empathic mirroring and compassionate response clearly see the suffering of others, embrace that suffering, counterbalancing painful resonances with the wise wish for others to find freedom from the harms that beset them. It is as if caregivers, patients, and families are rowing in a boat together. Should they all list to the same side at the same time, they would surely capsize and all end up in the water. Should

they all veer toward fear, anger, and reprisal in unison, they all would risk ending up as swimmers far from shore. At the same time, the leaning body of another predisposes them to empathically lean in the same direction. Thus, the trick is to see the other as a differentiated part of the same system, to hold the other in tension with one's self. If one caregiver sees the listing of her next companion on the bench to the left and counterbalances her toppling, they both might have a chance to remain seated at their oars. Caregivers know this intuitively, but now neurophysiological approaches explain with greater understanding how social relationships shape neurological structures. There is a language for explaining how the compassion one feels for others counterbalances the suffering one sees in the world. These feelings of compassion necessarily entail action on the behalf of others. Chaplains can explain how empathic elements serve as inputs to compassionate responses that transcend empathy (Halifax, 2018). One not only sees and resonates with suffering (empathy), but one wishes that the sufferer might be free of suffering and then takes motivated actions to set the sufferer free. New maps of the nervous system have improved the scientific view of how human bodies and nervous systems in relationship maintain the complex balance of mutually supportive care.

What does meditation have to do with it?

Stories are necessary for the integrative healing enabled by two or more people who deeply listen to each other. Yet stories also tend to reify one's identity and reduce one's flexibility to hear another perspective in conflict with one's story. As anthropologist Jackson (2002) made clear, stories rework subject and object relations, so that someone victimized by violence whose body was the object by which a perpetrator wounded their selfhood can return to the position of subjectivity (Jackson, 2002). Survivors tell narratives about themselves in order to find a sense of belonging in a local world. They find their social location in the act of telling a narrative about themselves in relation to the social context in which they find healing. By telling their story to a receptive audience, victims rediscover social belonging. They discover themselves as survivors. "To belong is thus to believe that one's being is integrated with and integral to a wider field of Being," Jackson (2002) writes, "that one's own life merges with and touches the lives of others" (Jackson, 2002). A survivor tells a story that means she is not longer imprisoned by the lingering effects of silent shame. Through telling a story, she navigates between the personal and public worlds. All the same, once a survivor begins to tell stories that hold others accountable for her suffering, it is often difficult for her to refrain from blaming perpetrators for aggressive acts that threatened her being. Some survivors tend to blame others in their stories for the suffering others caused, and this work of blaming often occurs implicitly. Survivors often narrate their

stories in such a way that they reaffirm their own goodness at the expense of their enemy's badness.

But survivors also tend to evaluate themselves as lacking or faulty, as damaged and defiled, as inferior along any number of axes in comparison with others. A survivor might find herself playing the game of feeling superior to some and inferior to others. She may feel superior for her righteous suffering and endurance. She may feel inferior because of her vulnerability and complicity. These narrative and evaluative schemata often populate the mind of survivors without explicit awareness. In support of this view, recent research shows that the when the brain is idle default mode network that link together the midline brain regions that highlight the self and spin narrative interpretations of experience (Vago & David, 2012). This is task negative behavior, meaning it occurs when subjects are not actively engaged and focused on a task at hand. Vago and David (2012) offer their position based on the empirical data that "maladaptive habits, distorted perceptions, and biases accumulate through the conditioning or reification of the narrative self, most of which is not accessible to conscious awareness." Mindfulness meditation practices, and other formed of focused attention practices, act as "the master regulatory mechanism for de-coupling and efficiently integrating experiential and narrative self modes of processing with the potential to transform the reified self from maladaptive trajectories into more positive, adaptive trajectories" (Vago & David, 2012). Through increasing skill in mindfulness practice, one can down-regulate fear, rework and extinguish biases, and learn to clear the interior spaces of mind, nervous system, and body to receive others in their fullest expressions.

Focused attention (FA) contemplative practices include mindfulness meditation, centering prayer, Tibetan Buddhist versions of *samatha*, and Japanese *zazen* just to name a few of the more well-known forms it takes. Some recent scholars argue that yoga is a FA mindfulness practice that uses postures to activate and mindfully engage with bodily sensation (Emerson & Hopper, 2012). In any event, as Fox et al. (2016) summarize in the their meta-analysis of contemplative neuroscience research on focused attention meditation that these forms of meditation practice cultivate insular cortex, sensory-motor cortex, and the dorsal anterior cingulate cortex activation, while dampening the activity of the thalamus (Fox et al., 2016). The thalamus functions like a gatekeeper of neural information entering the brain, and meditation gives one more control over this neural structure. Focused attention meditation gives one greater ability to integrate bodily sensations of the viscera, which is associated with the insular cortex, into consciousness. Focused attention meditation allows one to change one's relation to bodily sensation in such a way as to adjust the function of the thalamus to permit more bodily sensations to enter into the conscious mind. In effect, meditation strengthens self networks

that promote de-centering from one's cognitive and evaluative experience, so that the meditator can attend to others with less self-preoccupation and more skillfulness. One is no longer the central character of one's story, but caught up in a vast ensemble of characters. Mindfulness practices promote tolerance of distressing stimuli in the body and greater tendency to approach negative stimuli (Davidson & Begley, 2012). Mindfulness helps one place one's awareness outside self-referential thinking.

Do these brain studies describe exactly what happens when a skilled chaplain frees her mind from self-referential thinking so she can focus on the story and embodied experience of patients and their families? Does neuroscience research provide maps for the brain correlates activated when a chaplain leans into uncomfortable, ambiguous, or disquieting emotional content or conflictual family or institutional dynamics? Unfortunately, neuroscientists have not confirmed through empirical study that these neural linkages become activated when a spiritual caregiver listens to a patient. Research on spiritual caregiving has not confirmed the neural correlates of compassionate spiritual caregiving through brain imaging studies that map the brain activity of chaplains in the act of giving care. It would be rather difficult to gather such data, and would mean expanding the studies of contemplative neuroscience from relatively unspecialized beginners or expert meditators to other practitioners of compassionate arts. Therefore at this point, one can only infer that the activation of the neurological ensemble I point to above is what happens in the brains and bodies of chaplains when they listen compassionately to persons, families, or other caregivers in crisis. At the same time, I would defend my view that it is justifiable to infer that chaplains can feel viscerally the stories of others based on the neurobiological research data and theories culled from controlled studies conducted in laboratories.

Does research prove that compassion actually leads to better medical and spiritual care for patients and their families in healthcare settings?

The simple answer is: not conclusively, at least empirical qualitative study has not so demonstrated yet. Studies suggest that compassion training enhances care, but the methods for researching character traits like compassion in an empirical way that takes into account patient perspectives and interweaves subjective and objective data are newly emerging. Researchers on the effects of compassion in caregiving have yet to demonstrate convincingly that compassion produces measurable outcomes for patients. A recent scoping study by Sinclair, Norris, et al. (2016) points out the the marked lack of empirical evidence for the effects of compassionate care. Only two of the 648 studies they studied analyzed actually included any reference to patient experience. The qualitative study of patient notions of what comprises col-

laborative compassionate care remains shrouded in the mystery of silence. As of yet, patients have provided feedback mostly through satisfaction surveys and patronage of medical institutions that they prefer. Most of the studies analyzed by Sinclair, Norris, et al. (2016) or Pfaff and Markaki (2017) referred to the experiences of caregivers (Pfaff & Markaki, 2017; Sinclair, Norris, et al., 2016). Moreover, many of the studies lacked a clear definition of compassion that differentiated it from other forms of interpersonal feeling like sympathy and empathy (Sinclair, Norris, et al., 2016). For these and other reasons, Sinclair, Norris, et al. (2016) lament, "compassionate care is expected by patients and is a professional obligation of clinicians; however, little is known about the state of research on clinical compassion" (Sinclair, Norris, et al., 2016).

As contemplative neuroscience gains precision in differentiating the neurological correlates of compassion from empathy, further study of what compassion means to patients and their families in clinical settings is needed. While it makes sense to base healthcare's vision of what compassionate care looks like in empirical sciences like neuroscience, it also makes sense to incorporate the patient's vision of what compassion is as well. Coordinating between qualitative research that includes patient accounts, neuroscience studies, and religious traditions will produce the richest descriptive and predictive models for collaborative compassionate care. However, at this point, few researchers have included the patient view on what compassionate care means to them. Nor have many researchers attempted to measure the effects of compassionate care on patient health outcomes. Empirical, qualitative study of compassion in live settings, in the field of healthcare, might support or contest the intuitive notion that compassion actually improves caregiving. As Sinclair, Norris, et al. (2016) state, such studies that take into account patient experience have yet to be done.

It is clear that very little meditation training provides marked benefits in terms of neural integration to religious adepts with over ten thousand hours of time practicing open compassion (Goleman & Davidson, 2017). It seems that the reason for this is that human beings have basic neurological structures that strengthen empathic resonance, perspective taking, and compassionate response. Humans are designed to support one another in close-knit communities as the evidence from neurophysiological studies conducted by Porges (2017) so ably demonstrate (Porges, 2017). Compassion happens for most people quickly and effortlessly given the right conditions, that is when caregivers are not distressed and riveted on their own survival. At the same time, the greater the time cultivating compassionate response through mind training, the more robust and instantaneous the compassionate response of the caregiver. Tibetan adepts studied by Richard Davidson like Mingyur Rinpoche show nearly instantaneous control over activation of the neural networks

correlated with compassion and much thicker interconnection of neurons in these regions (Porges, 2017).

In addition, the effects of lovingkindness and compassion meditation appear quickly in novices practicing meditation; they seem to take place after as little as eight hours of practice (Porges, 2017). What is less clear is how these effects cross the boundaries of physical bodies. If I interact with a compassionate yogi like the Dalai Lama, how quickly will our interactions have a dose effect that changes my internal states and character traits? How can these changes be measured? Is it enough to know them merely through subjective reports or is it necessary to correlate images of changes in the neural structure of patients with subjective reports of wellbeing? My sense is that the more sources and kinds of data caregivers have, the more comprehensive their view of caregiving will be and the more skillfully they will be enabled to care.

In another study published by Sinclair, McClement, et al. (2016), a grounded theory approach revealed that palliative care patients often associated compassionate care with caregiver virtues that they preferred. Patients cited a host of virtues caregivers displayed that embodied relational communication and person-centered care like "demeanor", "attentiveness", "vulnerable affect", "listening and supportive words," and "attending to needs" (Sinclair, McClement, et al., 2016). Indeed Pfaff and Markaki (2017)'s study advanced the over-arching finding that "patient and family centeredness" is "the primary structure for collaborative compassionate care" (Pfaff & Markaki, 2017). The essence of compassionate care is valuing people more than rational bureaucratic processes of caregiving that govern the provision of care in clinical settings. Sinclair, McClement, et al. (2016) suggest their study is preliminary to systematic research on compassion once an empirical measure like a compassion inventory is developed from work like their own. They say, "a measure would provide the means to conduct future randomized controlled trials and to evaluate education interventions" designed to train caregivers to be more compassionate (Sinclair, McClement, et al., 2016). Can Sinclair and his team's work add to the current discussion on the value of compassionate care to social healing as a form of justice? If so, how?

The state of research supports the conclusions that compassionate responses involve neural circuits that are different from those activated during empathy. Compassionate response converts the emotional resonance of empathy into actions on behalf of the suffering person the awakens feelings for another. By converting empathy into activity to help, compassion has a prophylactic function. As feeling and motivated action, compassion integrates the brain (Siegel, 2018). Compassion has a protective function for the brain whereas empathy does not, because compassion translates one's feelings for another (empathic resonance) and think-

ing like another (perspective taking) into action on their behalf (Klimecki, Leiberg, Ricard, & Singer, 2013). If more empirical research showing the results of compassionate care on patients existed, it would strengthen my argument here. As it stands now, what research exists points in the direction of compassion being a key ingredient in caring and supportive interpersonal relationships in medical institutions and beyond. As Sinclair, McClement, et al. (2016) find, communicative practices that make space for listening to patient stories, complaints, and concerns are essential to compassionate, person-centered care. Collaborative compassionate care involves feeling for, understanding, and taking motivated collaborative action to improve the situation of someone in pain or moral distress. This kind of caregiving has noticeable but limited positive effects on caregiver and patient alike.

How do stories heal wounded bodies and minds?

Storytelling events have profoundly integrative consequences in personal, interpersonal, and social dimensions. The human nervous systems and the human brain are complex systems that maximize the differentiation and integration of function and experience. The biological fact of neural differentiation and integration has important implications for storytelling and its ability to heal wounded persons. Once a person has regained a social context characterized by physical safety, they can again access their social engagement network. If the wounding they suffered is extremely prolonged or takes place early in life, the psychological patterning caused by trauma and abuse requires more energy and effort to undo. In any event, the survivor of trauma often regains a sense of internal cognitive and affective coherence but faces significant disintegration of memory. Fragmented memories lodge in the implicit memory systems of her body, triggering drastic and startling overreactions to common stressors. Traumatic memory intrudes in daily life and disrupts social interactions. In the context of a securely attached and attuned relationship, a survivor has the opportunity to rework and integrate these memories and achieve greater awareness of the wholeness of her being.

Research that describes the neuroanatomy of traumatic memory explains how amygdala-hippocampus-neocortex relationships, under the influence of stress hormones and sympathetic arousal, prevent the integration of implicit traumatic memory into a survivor's explicit memory and awareness. Since the right and left hemisphere of the neocortex are associated with different functions necessary for storytelling, a story strengthens the connective fibers linking the left to right hemisphere of the brain through the corpus callosum (Siegel, 2011). Since the right hemisphere links with bodily experience, left and right hemispheric integration also brings bodily experiences and memories back into conscious awareness. The linguistically adept and linear left hemisphere in-

corporates the bodily awareness, emotional experience, and autobiographical memory of the right. Thus in the aftermath of trauma, coherent storytelling reassembles a whole self (Siegel, 2011). This whole self integrates experience laterally and vertically. Without trusting and safe relationships in which to explore and integrate these fragmented bodily sensations, affects, and emotions, they linger in the relationships between the extended nervous system and body and resurface in intrusive ways. I would argue that everyone carries such fragmented memories in their interior world, to greater and lesser degrees, and these fragmented memories tend to resurface especially in moments of crisis. We are all survivors of various sorts of traumas, and we all need attuned listeners to hear our stories.

This is why spiritual caregivers play such an important role in clinical and penal settings. This is also why Willingham says spiritual caregivers have a social role that extends beyond clinical and penal institutional contexts. Contemplative chaplains have the training and inner dispositions cultivated through spiritual disciplines that dampen fear responses so that they can maintain a receptive stance toward stories that other people are habituated to deny. An attuned caregiver provides the social space in which a trauma survivor can then knit themselves back together. Trauma and illness survivors need an interpersonal context in which to heal, a social space in which to discover the moral lessons that trauma and illness teach. In the trusting interpersonal context established in a support group, attuned family, or therapeutic relationship, survivors can exercise ever greater self-autonomy and self-empowerment as a means to integrate themselves as they recover their stability and self-possession.

Telling stories, in combination with contemplative practices and other means by which to improve social and emotional resonance, promotes the integration of bodily sensations and implicit memories that trauma lodges in the body substrate. Mindfulness does this by strengthening the connection of the insular cortex, anterior cingulate cortex, dorsal and ventral prefrontal cortices, thalamus, brain stem nuclei, and distributed nervous system that always and everywhere collaboratively shape consciousness with the inputs of bodily tissues. Storytelling does this by interlinking the left and right hemispheres of the brain with the hippocampus and distributed nervous system. The strengthening of these neural networks is correlated with greater awareness of the interior, visceral states of the body,[13] increased ability to inhibit or modulate fear, and the improved ability to empathize with or intuit the minds of others. Hence, once a person reintegrates her experience after surviving trauma, she will herself be in a much better position, because of her changed neurobiology, to offer attuned care to others. Moreover, her visceral experiences of healing will likely inspire her. She will learn

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[13]See Antonio (2018)'s final chapter of The Strange Order of Things.

from her own suffering and healing to offer compassion to others. This, in part, explains the preponderance of spiritual caregivers who themselves first benefited from another's care in a time of crisis.

What are the social and institutional consequences of spiritual caregiving in the culture of sexual violence?

Most of us in an academic setting openly acknowledge that certain types of bodies have suffered more intensely and more often than others in the history of our nation and world. In the context of a religious communities, some of the most persuasive voices in Zen address how race, gender, and sexuality mark experiences with suffering and the path to liberation.[14] The question is what to do about these problems of unfair treatment of socially marginalized others. At this point in my argument about the value storytelling and attentive listening, I want to narrow on only one of the three dimensions—race, gender, and sexuality—to explain spiritual care's essential role in healing from sexual trauma. Sexual trauma and interpersonal violence are rife in today's world and have been throughout history it seems. Consider that numerous women and men belonging to every social, ethnic, and economic group have survived sexual violence in various forms throughout history. Recently, public health researchers have publishes results that make it clear how frequent sexual violence occurs. For example, Breiding (2014) reports that "an estimated 43.9% of women and 23.4% of men experienced other forms of sexual violence during their lifetimes" (Breiding, 2014). These "other forms of sexual violence" do not include rape, but they were sexually coercive and aggressive acts that caused psychosocial harm nonetheless. Such are the realties of violence in the social history of our species in the US and worldwide.

All this data about sexually-based interpersonal violence says unequivocally that the scale of violence that human beings experience in the late modern context is so vast and the damage so great that touches all of society of some way or another. Currently, health systems and universities are establishing more violence prevention programs or supporting more comprehensive healing efforts that survivors and bystanders can implement and access to prevent or heal from sexual trauma. The most pernicious aspect of unaddressed sexual trauma is that the damage tends to fester if unattended. While race, sexuality, and gender mark the particular forms of traumatic imprint in any body with different degrees of severity, all bodies wither in their exposure to the traumatic forces widely distributed throughout late modern societies. Sexual violence is intersectional, the more dimensions of one's marginalization from resources and power heightens one's risk, but it is also commonly experienced by powerful and well-resourced women. It makes sense to pay greater attention to healing in historically marginalized groups, but access to healing practices needs to be widely distributed

throughout society. The violence is everywhere, and so is the need for healing.

Social movements like the Movement for Black Lives or metoo argue for extending preventative methods and healing practices into marginalized communities with unprecedented intensity. In this work, forms of compassionate caregiving could play a significant role as movement, clinical, and penal chaplains introduce spiritual caregiving interventions like empathic or deep listening, person-centered spiritual care, and the ministry of presence. Making collaborative compassionate care the standard in healthcare could greatly improve the quality of care in hospitals, hospices, and health clinics. The primary mechanism by which to stabilize marginalized communities is to ensure that social institutions distribute material resources, such as medical and spiritual care itself, more evenly across social groups so that more groups feel safe, cared for, and resourced to face the daily challenges of life. As a secondary measure, social institutions need to attend to the work of spiritual healing, personal and interpersonal integration, and transcendence. Social and economic equality are naturally linked, and social justice cannot attend to one and ignore the other.

In this spiritual work, it is not so much that social institutions need any particular type of narrator to stop telling stories, though the leaders and members who participate in social institutions may need to increase the attention paid to black, women, LGBTQI persons in the social sphere. Bringing marginal perspectives to the light of the public sphere involves two steps. First, social institutions like hospitals and universities need to engage in qualitative study of the perspectives of these marginalized communities so as the figure out what they think compassionate care looks like. In the instance of sexual violence, how do sexually violated people suffer and what does compassionate care look like to them? Qualitative studies of these perspectives need to be understandable to broader publics in the public sphere. Second, social institutions like hospitals and universities need to equip more audiences—through practices that cultivated receptivity to otherness like decentering and cultivating a non-judgmental listening presence—to value all stories no matter the harsh truths that they tell. Careful research has proven that mindfulness mediation practices can enhance these character traits associated with empathic and compassionate presence, (Goleman & Davidson, 2017; Vago & David, 2012), but other spiritual disciplines might do so well. Analysis of complex trauma argues for the application of such spiritual interventions at several levels: social, interpersonal, and personal. This is so because this not a problem confined to any particular set of social institutions, but is shared across organizational fields like health care, education, the military, and government.

Along these lines, the research of Felitti, Anda, Lanius,

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[14]See for instance Manuel (2015) and Brown (2018).

Vermetten, and Pain (2010) on the pervasiveness of trauma indicates that complex trauma contributes to diverse problems like imprisonment and chronic medical conditions.[15] One of the legacies of the growing awareness of complex trauma in the therapeutic community is that it caused the type of long-term irremediable interpersonal dysfunction in patient populations that led trauma theorists to formulate a new diagnosis and approach to therapy. The attachment, self-regulation, and competency (ARC) framework developed by Kinniburgh, Blaustein, Spinazzola, and Van der Kolk (2017) at the Trauma Center in Brookline, MA recognizes the desperate need to stabilize family systems, attachment networks, and the physiologies of children and parents threatened with systematic violence (Kinniburgh et al., 2017). The self-regulation of child affect can only take place in the context of stable parental attachment relationships, so effective therapeutic interventions must first stabilize parents and caregivers in relationship with their children. Stabilized children, parents, and caregivers regain the capacity to access the integrative work of story that connects the members of family into one compassionate community. Once the symmetry of parents and children collectively regulating affective experience prevails, stories offer human communities an invaluable way to become aware of, regulate, and transcend the personal self.

Without the co-regulation of affective experience, a fearful symmetry in the form of a negative reciprocity threatens to plunge families, communities, and societies into chaos. The lex talionis rule of this state of affairs is, "Because I have suffered, now I will make you suffer. Because I have received punishment, now I will punish you." One merely translates between modes of exploitation and predation, turning one's history of victimhood into a justification to victimize others. That this occurs is natural. The transcendence of this vicious circle is just as natural, once the members of human communities regain their freedom to act with care for one another. Often the rule of violent retribution functions implicitly, schematically, and without self-conscious awareness. It is the ghost that animates the machine of punishment in a society that no longer finds displays of punishment in the public sphere palatable. Here is where spiritual caregivers can take part making the sacred space where survivors can beat swords into plowshares. To keep creating ghettos of interpersonal punishment, in Folsom State Prison or Appalachia or Yemen or South Chicago, is not a socially sustainable or socially responsible solution to violence on the global scale. Such a way of handling violence leads to shrinking islands of peace. To silo such interpersonal dynamics of violence can only presage more widespread social harm.

Conversely, to create an inspired host of receptive spiritual caregivers does some amount of good in a world where violence touches the lives of so many. If a spiritual caregiver cultivates the emotional balance and moral intelligence

to listen to someone else's story, she can open new worlds of healing between herself and the person she hears. These worlds of healing have no natural limit: they have in them the energy of the infinite—a quantum holism. This hearing then enables greater interior integration for the spiritual caregiver, patients, families, and whoever else participates. The gift of listening returns to the caregiver in the form of greater insight about herself in relation to others. A similar alchemy happens for anyone else who takes part in the work of relationship. Separated by their various bodily imprints of violences suffered, caregivers and patients can tend to each other with care, like the right hand that bandages the left hand and the left hand that bandages the right hand that both have but recently escaped the flames. Better to heal scorched flesh than to make sure all humans are equally licked by the flames of suffering.

It is a dire need to understand with more clarity the contribution collaborative compassionate care has to make in medical and spiritual caregiving through more robust empirical study. In this pursuit, researchers have failed to sufficiently tap into the data that ethnographic study of patient views reveal about how patients perceive of compassion in healthcare settings. Maybe the stories that patients tell of excellent and substandard care, collected by diligent ethnographic researchers, can eventually serve as the exemplary tales that guide the skillful care of chaplains, nurses, and doctors in the context of a drastically altered health system will focus on person-centered care. Maybe this person-centered health system will support modest but sustainable reforms in social institutions more broadly that value the bodies, minds, and experiences of all more equitably.

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[15]Van der Kolk (2015), 145-149. The section reporting on Felitti et al. (2010) research on the Adverse Childhood Experiences (ACE) goes by the title "The Hidden Epidemic."

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A Classical Framework for Assessing Beauty in the Fields of Science and Engineering

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Beauty is that property of an object which clearly communicates itself to the object's perceiver, who is so pleased by what he perceives so as to inspire a movement of his will toward that object's beauty. Beauty is true and it is good, and it greatly enriches all aspects of human life. The sciences are no exception, as they too can be enriched by beauty. As science is concerned with the pursuit of truth for the good of all, it is only natural that beauty be a part of its patrimony. As such, beauty and science are assessed together in this article to find places of mutual enrichment and benefit. An internally consistent framework is presented herein which defines what beauty is and how to critically assess it. This framework is classical in origin and is re-presented here to a modern audience. Once properly understood, this framework can be used to objectively discuss and analyze beauty, particularly within the context of scientific and engineering disciplines. Examples are given to demonstrate how beauty can be better implemented into the sciences with respect to figures, presentations, and products. The ultimate goal of the work is to encourage the critical discussion of beauty and to empower scientists to more beautifully present their research.

There are certain attributes which are commonly valued across various scientific and engineering disciplines and even across different cultures. Beauty is something which has captured the imagination of people everywhere and in every age. Indeed, beauty inspires a movement of the human will towards a beautiful object. In the case of scientific research, more beautiful research should help attract the attention of the community. This has direct benefits in the field of science, as one of the final aims of science is to disseminate scientific findings as widely as possible to the broader community.

Several classical definitions of beauty will be presented and properly contextualized within a classical worldview. The benefit of this approach is that a systematic metric is defined by which beauty can critically, intellectually, and impartially be assessed. This offers distinct advantages over what is most often characterized as a subjectively emotional response to beauty. Beauty (along with other supplemental terms) will be defined and case studies presented to demonstrate how beauty can be best understood within the field of material science and engineering, for example. Assumptions made within this framework will be stated where appropriate. This is not a critical review of the classical understanding of beauty, but rather, an introduction into existing frameworks with which to discuss and even appreciate beauty. As such, select resources will be highlighted in this treatment which exemplify the following approach.

Defining Beauty

Four perspectives will be presented with which to conceptualize beauty. These perspectives are not mutually exclusive but synergistically define what beauty is and how to discuss it. The perspectives are internally consistent with one another and build upon one another as presented herein. When considered together, a clear understanding of beauty is constructed.

That Which is Transcendent

As already indicated in the introduction, mankind's fascination with beauty transcends time and culture, making it a truly transcendental phenomenon. Indeed, beauty, truth, and goodness have traditionally been classified as transcendentals – as integral aspects of what it means to exist (Schindler, 1991). Everything that exists has being (existence). Everything that exists also has a nature (or an essence). For example, the author is a human who has a nature which is universal to all humans, while retaining his own particular personhood which is unique to himself. This will be elaborated shortly. For now, it is enough to say that everything that exists has, at least, these three transcendental qualities. A transcendental is a property of being (Schindler, 1991). Everything that is, is true, is good, and is beautiful. It can even be said that the transcendentals themselves have a shared nature that is in turn true, good, and beautiful. Each transcendental, since it exists as a real thing, has the properties of being which are truth, beauty, and goodness. Or to put it another way, that which is true is also good and beautiful. That which is good

is true and beautiful. Finally, that which is beautiful is true and good. This supplies us with our first definition of beauty – that which is true and good. Beauty can be qualified on the basis of truth and/or goodness. Religion is the human pursuit of goodness, which will not be treated here. Art is the human pursuit of beauty, which will be touched upon in part. Science is the human pursuit of truth which will be our focus.

In modern times, science has commonly been reduced to the study of those things which can be empirically demonstrated or studied; things which can be measured, tested, or experimented upon. This is a deviation from the traditional scope of science, which would include the pursuit of all forms of truth and not simply empirical or material truths. For this reason, Aristotle properly refers to things like ethics, politics, and physics as sciences, for example (Aristotle, 2013). It is a modern innovation to assume that the only form of truth is the empirical form of truth and that other forms of truth do not exist, such as those which can be determined by reason and logic. When considering that beauty is true and good, a severe injustice is incurred by reducing truth merely to empirical truths. It is difficult to experimentally or empirically measure how beautiful something is. Since it is very difficult to empirically determine if something is beautiful, people will tend to avoid discussing it in terms of objective and intellectual criteria. This moves discussion about beauty from the objective to the subjective, where beauty is relegated to the personal and emotional response of the individual. Once this underlying assumption about empirical truth is applied to beauty, all critical discussion is curbed, and each person is able to determine for themselves how beautiful something is. Who am I to say if something is beautiful to someone else, unless I have an alternative metric by which to assess beauty? The alternative to the modern subjectification of beauty, is a return to the more traditional worldview of being, beauty, truth, and goodness.

With these definitions of truth, goodness, and beauty at hand, it is possible to begin to assess beauty, particularly within material science and engineering. Since a beautiful thing is also a true thing, the sciences are instrumental in helping us to understand what beauty is. Being concerned with the properties of matter from which our world is constructed, material science is particularly pertinent to discussions concerning beauty, as beauty is conveyed to us by the material of this world. To put it another way, material science is concerned with substantial forms or the nature of substances like silver, iron, or bronze. Beauty is concerned with accidental forms of the nature of things as they exist as objects like a ring, a necklace, a statue, a painting. The substantial form of bronze is the same whether it is in the accidental form of a statute, a shield, a bowl, etc. The substantial and accidental forms can exist together in harmony as the nature of a thing being a bowl in no way excludes the nature of that

same thing being bronze. They work together as much as the material and the immaterial work together. In the natural world, matter never exists without form. Matter exists in possession of a form like copper, wood, table, etc. Ultimately, as composite beings of spirit and body, it is through the perception of the material world by which we come to know truths about the nature of things and by which beauty is communicated to us (by our intellect). We cannot directly perceive tree-ness or tree form with our senses from the natural world, but we can perceive tree trunks and branches and roots and leaves and so on. By the observation of many trees we come to abstract the tree-ness of what it means to be tree, or the nature of a tree. The role beauty plays in how these truths are communicated to us will be elaborated shortly.

An important assumption of the current framework is that truth does exist and can be known. Many in the modern culture argue a relativistic world view in which there is no absolute truth (it is something that each person makes for themselves), this reduces beauty (and other aspects of life) to a personal emotional response subjective to each person. This poses challenges to the sciences. In science, there is no room for relativism. Science is founded in the conviction that there are knowable, objective truths that are true for everyone in every time and place. We call these truths laws when they are so true that they have never been observed to be untrue (as with the laws of physics or the laws of thermodynamics). Indeed, the more powerful a law is the more universally it explains the world around us. Other scientific truths exist as well such as principles and theorems that, while not elevated to the status of law, are also held to be true. Without this common understanding of objective reality, science could not have flourished to the extent it has. It is helpful to introduce Aristotle's principle of non-contradiction here. It states that it is impossible for something to be and to not be at the same time and in the same manner (Aristotle, 2013). This is an underlying assumption in the philosophical sciences and the natural sciences as well. The first law of thermodynamics cannot be true for me and at the same time not true for you. It is always true for everyone. In this way, the scientific tradition firmly holds that there are objective truths that are knowable by us. Another popular objection is that truth might exist, but it is impossible for us to come to know what the truth is. This is again incompatible with the scientific tradition. Scientists throughout the centuries have pursued truth with the strong conviction that it is indeed knowable to us. Within Material Science and Engineering, for example, exists a significant discipline of characterization, devoted to the discovery of the structure and properties of materials of interest. Many and various techniques have been developed to assist us in coming to know the truth about our world. Even things which cannot be directly observed have become known to us through careful experimentation and logical deductions from experimental results. With all of this in mind,

it should be noted that a classical worldview and the scientific worldview both converge on the fact that truths exist and that these truths are knowable to the human mind. There is a confidence in the epistemological powers of the human person, or the ability of the human person to know truths and have confidence in those truths.

That Which is Most Easily Knowable by the Radiance of its Being

Thus far, beauty has been described as a transcendental, or a property of being, that is common to all things. All that is, is beautiful. However, with what kind of intellectual and objective framework do we compare the relative beauty between different things? How can we compare the beauty of one thing to another? Following on the transcendental framework we have developed, it would seem that a more beautiful thing is that which is more true and more good. We will focus more on the aspect of truth than on goodness in this treatment because the scientific institution is concerned with the pursuit of truth and also because this treatment is tailored to the perspective of the Material Sciences.[1] To know the truth about something is to know what it is, what the nature of that thing is. We come to know the truth about a tree by knowing what tree nature is. We come to know what tree nature is by studying lots of trees. Dendrology is the scientific study of trees. There is a scientific study of almost anything you can think of, with certain traditions being held in common across those studies. The scientific tradition is very fond of three things, for instance, which would be helpful to review: observations, definitions, and replications.

One way to determine the nature of something is to observe it. There is a philosophical principle that action follows upon nature. The way something acts is a result of the way it is. Dogs bark and chase their tails and run with the pack. Metals conduct electricity, donate electrons, and have a sheen. By observing the actions (or properties) of things, it is possible to come to an idea about the nature of a thing. This is precisely what happens in science when a scientist asks, "what is the nature of gravity?", after having observed that such a thing as gravity exists. Once the question has been postulated, more observations are made. When the actions of a thing have been thoroughly observed in their natural course, different observations can be made as to how a thing acts in response to a perturbation made by the scientist; experiments are conducted. With enough observational evidence conclusions can then be drawn about the nature of a thing. Indeed, it is clear to see how this principle of action following nature fits within the scientific method. Perhaps within every scientist is the hidden thought "why does this thing do what it does. What is the governing principle (or nature) that makes it behave the way it does?". It should also be noted what other sorts of underlying assumptions are implicit within this framework. Namely, that the world is

intelligible and that the world around us is subject to experimentation (Ratzinger, 2004). It is easy to see then, how the scientific revolution manifested itself in the Western World, which believed at the time that the world was created logically and that the impersonal world is itself not divine and can be tested, prodded, and experimented upon.

Another pastime of the scientific endeavor is an astute attention to detail, especially with definitions (to the chagrin of many students). Meticulous detail is paid to defining things and terms in science. Indeed, once the nature of a thing has been identified through observation, it is named and defined. Whether by words or equations, there's a scientific definition for metal, electron, gravity, zwitterion, etc. Each definition names something universal about the things which the definition defines. Gravity has the same nature here as on Mars, while being particularly distinct in each instance. My computer has a real computer nature that is particularly manifested by my computer, while still having the same computer nature as my lab mate's computer. In this way, there is an objective truth that exists within the object and definitions and nomenclature name something real about the object. This harkens back to Plato, who proposed that particular objects which might be beautiful are only so because they really share in the nature of The Beautiful (universal)(D. Plato Gallop, 1999). There are other ways to explain how universal terms are applied to particular entities, but the realist way shown here is the most coherent within the framework presented for defining beauty.[2]

One more staple of the scientific process is the virtue of replication, or duplication. It is evident that when relying on observation to determine the nature of a thing, it is good to rely on many observations rather than few. In science, results are favored which include many trials of replicates to ensure that what is concluded about the nature of a thing actually correlates to the truth of that thing's nature. Suppose that if a young child from an arid climate were to watch Mary Poppins, they may conclude that umbrellas are sometimes useful for flying from place to place if they did not have enough observational experience to know that in reality, umbrellas are best implemented to keep oneself dry from precipitation and not for flying (unfortunately). From many observations of particular things, scientists come to abstract the nature of

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[1]We will not focus on goodness for the sake of length, not because there aren't also objective standards by which goodness can be assessed (again see the ancient philosophers, who had much to say about goodness and good living).

[2]Realism is the notion that a universal term names something real in an object, that there is a real nature contained within an object that makes it the way that it is. The reader should be aware that an alternative philosophy is that of nominalism, which holds that there is nothing real within the object that makes it the way that it is, but that it when a term is applied to an object, it is merely applied to that object in name only, and not to identify something real about the object.

A Glossary of Terms Appropriated Here	
Abstract	The process of consolidating a universal concept from the observation of many particular entities. In abstraction, the extraneous details pertinent to the individual entities are left behind and the universal common nature shared by all the entities is retained. Analogously, the abstract of a scientific paper should retain only the fundamental concepts of the study while omitting unnecessary details.
Accidental Form	The unique aspect of an object that makes it what it is. A table has a table form that, when applied to wood, gives rise to a table. The same material substance (say, bronze) can exist with different types of forms (shield, bowl, doorknob) while retaining the same substantial form (bronze).
Beauty	Four perspectives of beauty were discussed herein. Beauty was shown to be: · A transcendental; true and good · The radiance of being · That which is balanced in integrity clarity, and proportion · That which, when perceived, pleases
Form	All material things have a form. A form applied to matter gives rise to a thing's essence. The form of copper applied to matter gives rise to copper. The form of table applied to wood gives rise to a wooden table.
Nature, Being, Essence	As applied here, these are terms that describe what a thing is and what a thing does. Action follows upon nature. Being is distinguished as existence, or real-ness.
Realism	In this context, realism is the philosophical conclusion that universal terms can be applied to individual entities because of something real in those entities that is held in common for them all. There is something real about tree nature that the universal term tree is associating with.
Substantial Form	The unique aspect of a material that makes it what it is. Copper has a substantial form that manifests itself in a uniquely different way in matter than the substantial form of silver. While the accidental form of an object may change, the substantial form of the material from which it is made need not.
Transcendental	A property of being, or a property that all existing things possess. Beauty is a transcendental, because everything that exists is beautiful.
Will	The rational faculty of choice possessed by rational creatures. The will is informed by knowledge (from the intellect and the senses). The will is directed towards perceived goods.

the things they are observing. From observing many trees, we abstract the nature of tree as a universal concept and apply that concept to particular trees we may see in the future. Even if we have never seen a particular tree before, once we do see it we can tell it is a tree because it conforms to the form of tree we developed from our "database" of previous observations of other trees.

Now, since beauty is related to the truth of a thing, and truth is ultimately related to the nature of things (the conformity of a thing to its nature), we now arrive to our next definition of beauty. Beauty has also traditionally been called the radiance of being.[3] Something is more beautiful when it more perfectly signifies its nature to the exterior world. When an object's being is so radiant that it is obvious what it is, then it is beautiful. Simply put, for a thing to be beautiful we must ask if the outward appearance of the thing corresponds to that thing's nature. We've already discussed how we come to know the nature of things and how we abstract

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[3] In an analogous way, truth is the conformity of being and goodness is the excellence of being.

the nature of a thing from many observations of what we perceive about particular occurrences of that thing. In this way we abstract dog nature from the many individual instances in which we have perceived or observed individual dogs. In this way, when we see a dog in the future, we will know it is a dog because it has the form of a dog which corresponds to dog nature. If the outward appearance of that dog corresponds to its dog nature, then it is a beautiful dog. If beauty is the radiance of being, then a more beautiful dog is a dog whose appearance more perfectly corresponds to its dog nature. When we look at a beautiful dog we know instantly and easily that it is a dog. Indeed, beauty alleviates the mind from the arduous task of abstraction. We don't have to even think about what the dog is, we just know. In contrast, a less beautiful thing is a thing that puzzles us as we try to figure out what it is.

It is necessary however, for the observer to have enough sense experience (or observational data) to have a clear idea of what dog nature is. If someone had not seen many dogs before, they may not be certain that a chihuahua was a dog, nor would they think that it was beautiful, let alone a beautiful dog. Furthermore, certain conventions may exist which also influence our perception about a dog's nature. Along with dog nature there is also a common expectation of specific dog breeds, like dalmatian nature or German shepherd nature. A dalmatian and a shepherd both have dog nature, but they each retain their specific breed nature as well. For this reason, it is likely that someone might say that a pure-bred dalmatian is more beautiful than an ambiguous mutt, because while it is radiantly clear that both are dogs, it is unmistakably clear that the dalmatian is a dalmatian while the breed of the mutt is unclear. Since there is a convention that dogs have breeds, it influences how beautiful each dog is perceived to be. In another analogy, the same convention does not apply to cats. If someone were to see a typical Manx, they would immediately realize that it was missing something that cats are supposed to have - a tail! Since most cats we see have tails, the form of a Manx wouldn't correlate perfectly to the form of cat that most people identify. The first question is usually "What happened to their tail?" on the natural assumption that it must have had one at some point. Some are shocked to discover that Manx is a breed of cat from the Isle of Man which usually does not have a tail. The conventions about dog and cat nature informed beauty differently for these two examples. That is why it is important to realize how both conventions and observational sense experiences impact beauty. There are often conventions within various disciplines (like art and science) that are expected by their adherents and of their adherents. While it is possible to produce beauty outside of an existing convention, you usually have to be very good to achieve that end.

Returning to cats, most people, if given the choice between petting a tail-bearing cat and a tail-less cat would prob-

ably choose the tail-bearing cat (or the "normal" cat). This is because their will is directed towards the more beautiful cat. For our purposes, the will is the rational power of choice that humans possess which is informed by knowledge and directed towards an apprehended good. Most people have the expectation that a cat should have a tail and based on their knowledge of what a cat should be, would choose the cat with the tail. However, someone from the Isle of Man may indeed choose the tail-less cat (Manx or not) because of their additional knowledge about the Manx breed. Beauty is what naturally pulls on our will and draws us to an object in accord to what the will knows about that object from the intellect. In this way, a beautiful object communicates knowledge of itself to the perceiver and this knowledge informs the will in its choice to gravitate towards the beautiful object.

That Which is Perfectly Balanced in Integrity, Clarity, and Proportion

The way people normally react upon seeing a tail-less cat is an indication of how natural it is for us to expect something to have the integrity proper to its nature. There is just something off about a cat without a tail like there would be about a dog without legs (or a hot dog with legs). This points us to one more traditional formulation of beauty. A beautiful thing is that thing which is complete in integrity, clarity, and proportion (Aquinas, 2012). The more perfectly balanced a thing is with respect to these three attributes, the more beautiful it is. In one way or another, these attributes are oriented towards the form of the object (both substantial and accidental).

Much has been discussed already on the integrity of a thing with respect to its nature. A dog without legs is lacking in the full integrity (or the full unity, or wholeness) of what it means to be a dog. A dolphin without legs, however, does not lack integrity according to its nature. In this way, the integrity of a thing must correspond to the truth about that thing.

We have also touched upon clarity in discussing how clearly or radiantly the nature of a thing is conveyed by its outward appearance. Beauty is dazzling in its clarity. Although we may not always be able to pinpoint exactly what it is that captures our attention, we do know that it has been captured. This is a subtle clarity that speaks to us very loudly, but in a language we may not be able to understand until we have learned how to speak about beauty.

Proportion is the attribute of beauty that orders all things such that size, shape, material, color, etc., so that they are perfectly and harmoniously balanced together. A tie-dye colored cat would be more distracting than beautiful. The same would apply to a dog that has one leg that was twice as long as the other three. Here, symmetry is often a helpful component of proportion. There is often an underline symmetry or

geometric/arithmetic principle which guides the creation of art, music, and architecture.

Let's examine a practical example of integrity, clarity, and proportion from material science and engineering. Drug-resistant superbugs are a growing concern as bacteria are more commonly becoming "immune" to antibiotics. Copper ions are naturally anti-microbial, and bacteria can't develop resistances to them. Copper-based metallic alloys can be incorporated as components in a high-touch surface and designed to release a bacteria-lethal amount of copper ions through corrosion (Hutchison, Zhou, Ogle, & Scully, n.d.). For example, this copper alloy could be used to make doorknobs in a hospital to reduce the risk of infectious outbreaks. This alloy would need to consistently release enough copper ions to kill bacteria within a few minutes of contact with the doorknob. The alloy would also need to not corrode to the point where the doorknob looks unpleasantly corroded – a dirty looking doorknob is not a welcomed sight in a hospital (even though it is likely much cleaner than a shiny, stainless steel doorknob in terms of germs). These two requirements (release copper ions while not looking corroded) are seemingly at odds with one another. Additionally, the copper alloy would need to do this under the influence of human sweat/oil because this would be the most likely electrolyte in which corrosion would occur. Knowing how the alloy would need to act, we can begin to understand the nature of the alloy itself (since action follows upon nature). This will inform what is proper to the nature of an anti-microbial doorknob. If the final doorknob failed in any of these regards, it would lack the full integrity of an aesthetically pleasing, anti-microbial doorknob.

Here, the context of the situation matters. It matters that the doorknob looks aesthetically pleasing because it needs to appear to be worthy of a hospital setting, where dirty looking things can be unsettling to patients, care providers, and guests alike. A dirty-looking corroded copper doorknob while retaining the true nature of an anti-microbial surface would (by convention) have the appearance of a dirty doorknob to the normal observer. There would be a clarity problem, because the outward appearance would not correspond to the inward reality (the luster of being would in fact be tarnished; literally and figuratively in this case!). Instead, if the doorknob successfully looks clean aesthetically, and is actually clean medically, then there is a fullness of integrity, a luster of being.
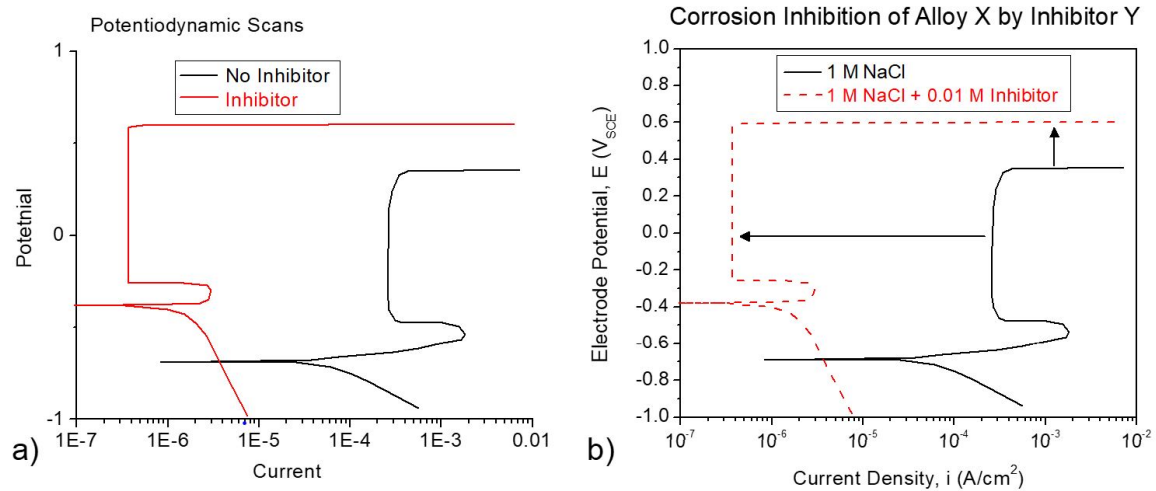
The appearance of the doorknob is an important factor in its final beauty. The common convention of what constitutes a dirty doorknob versus a clean doorknob is important in this situation, even though the doorknob could successfully be anti-microbial while breaking this convention. In this same way, it is fortunate in this case that copper-based alloys (brass, bronze, etc.) have already been used as a conventional material with which to construct doorknobs. In-

deed, even if a purple-colored alloy could be made that was anti-microbial, it may not be able to be deployed as a doorknob because it would lack the appropriate color normally expected for doorknobs. The purple color of the object would be disproportionate to the object itself. Likewise, the choice of copper over other metals is decided with respect to proportion. Silver ions are also anti-microbial and could in theory also be implemented in an anti-microbial, tarnish-resistant doorknob. However, using silver (an expensive and noble metal) to make (many) commonplace doorknobs would be an unproportionate (and inappropriate) material selection given the function of the final component.

Another example of how to apply these principles is offered in Figure 1, which presents two variants of a figure depicting the same data. Figure 1a is constructed as a less beautiful portrait of the data, while Figure 1b is constructed as a more beautiful portrait of the data. The caption highlights some of the features which are different between the two figures and how each feature relates to either integrity, clarity, or proportion. Integrity is absolutely essential for any figure which is meant to convey some meaning to the reader. If that meaning is lost upon the reader, then the figure may as well not be used. Cues which aid in maintaining the proper integrity of the figure (and the data) include informative labels, color- and symbol- coding, and correct spelling. The meaning of the data must be presented clearly to a general audience for them to understand. Ways for figures to be presented with clarity include proper use of text, color- and symbol- coding, and observance of conventions and customs. Lastly, proportion correctly balances colors, sizes, position, etc. to make the meaning of the figure more aesthetically presentable to the observer. Proportion plays an important role in text sizing, coloring, positioning, and symmetry in placement of figure elements. Ultimately, the goal of a beautiful scientific figure is to evoke in the observer the question "what is that?" with a sense of scientific studiousness. Conversely, a less beautiful figure evokes the question "what is that?" with a sense of confusion and distracts the observer from the true meaning of the data.

That Which, When Perceived, Pleases

That which, when perceived, pleases. This definition provided by St. Thomas is the final one we will discuss (Aquinas, 2012). A beautiful thing pleases upon being seen. This is not the same a beauty is in the eye of the beholder. Here Saint Thomas has in mind that a more beautiful thing pleases the more virtuous pleasures. He is assuming that the perceiver is a well-formed human person. A rather dull thing may appear beautiful to one person and a beautiful thing may appear rather dull to a different person. Everything we have discussed so far in this traditional framework has made the case for the objectivity of beauty – that beauty is in the object. This differs from subjective beauty, when beauty is in

Figure 1. Comparative assessment of how data can be presented in a lesser (a) and more (b) beautiful way.

the subject (the beholder). This is rather like the example of objective and subjective truth discussed earlier. It may very well be the case that something is subjectively beautiful to a given person for a reason only known (or unknown) to that person. However, not all beauty is reduced simply to subjective beauty. If this assumption is made, then no intellectual conversation about beauty can be had. However, with the current framework in mind, we are indeed able to engage in objective dialogue about the nature of beauty. To be clear, subjectivity does matter. A trip through the Louvre for a blind man, his young son, and his seeing eye dog will have a very different impact on each of them. For obvious reasons ranging from sensory experience, to attention span, to rational capacity, each subject will have very different subjective experience of the art on display. It is in this way that we see how the disposition of the perceiver influences the subjective beauty of the art. However, nothing about the art changes, the objective properties of the art are the same for all three subjects. Our previous discussion herein was made with respect to the objective reality of beauty. Since subjective beauty depends on the perceiver, we may maintain a metric for discussing the objective beauty of a thing by appealing to the subjective response of the person who is most disposed to perceive and be pleased.

Here it is helpful to discuss the classical understanding of pleasure. Plato wonderfully explains in his Republic the three levels of pleasure which correspond to the three powers of the soul: sensation, courage, and contemplation (Plato & Bloom, 1968). By analogy he compares the soul to the city which contains three classes of citizens: the common man, the warrior class, and the ruling class. In this way, Plato (through Socrates) enumerates the three levels of pleasure. The pleasure of sensation corresponds to the common crowd, which is easily swayed by feelings of happiness, hunger, excitement, thirst, fear, etc. This is the most common form of pleasure as it is available to all and often (as with eating). The power of courage which corresponds to the warrior class gives rise to the pleasure of conquest. This is a less common pleasure that requires time, effort, and the coordination of the lower bodily sensations such as achieving a promotion or mastering a new skill. The final, and highest pleasure is that of contemplation and it corresponds to the ruling class. The ruling class (in a happy city) orders all things justly in their proper place to the flourishing of all, just as the intellect should order all things in the human person. This is a rarer pleasure and requires the coordination of the whole person but is the highest of pleasures. With this in mind, we can see what St. Thomas means when he says beauty is that which,

when perceived, pleases. He has in mind the pleasures of all three levels of the soul, the highest of which is contemplation. The more beautiful a thing is, the more it pleases all three levels of pleasure. Within the context of the presented framework, a beautiful thing pleases the senses when it maintains integrity, clarity, and proportion, it pleases the sense of conquest when the mind can easily determine what the thing is, and it pleases the power of contemplation when the observer can rest in the beauty of a thing and take it into his own mind to contemplate.

The concept of appealing to all three pleasures of the soul can be exemplified in the construction and delivery of a scientific presentation. Briefly, we can examine how a beautiful scientific presentation might appeal to the pleasures of the senses, the pleasures of conquest, and the pleasures of contemplation. For sensory pleasures, it is important that a presentation have an aesthetically pleasing color scheme and that elements of the presentation are easy to read given the lighting of the room, the distance from the presentation to an audience member, and the quality of the medium of presentation. The presentation should not be overly hindered by text and should be constructed with a consistent scheme or format. When possible, it may be useful to engage the audience's senses by bringing in a sample that the presentation is about for them to see and touch in their own experience.

With regard to the pleasure of conquest, the presentation should be planned in such a way so as to bring the audience along in triumph after triumph. First by introducing the subject matter to them in such a way that they really do understand the unresolved problem at hand and where the current research stands with solving this problem. Having recognized together a problem in our understanding of some topic, the audience can then be invited to solve that problem with the presenter by developing an experimental procedure to answer unknown questions. When data is presented, the audience should be guided to the point where they understand what the results mean and how it relates back to the problem at hand. Finally, at the close of the presentation, when conclusions are made and the problem (or at least some aspect of it) has been solved or understood, the audience should also feel as though they have come to solve the problem too; they should feel a sense of conquest. If at any point in the presentation an audience member feels as though they have lost you (either in understanding the material, or in their attention span) then they have indeed lost something, there can be no sense of conquest in that moment. Worst of all, is if they feel like they have lost twenty minutes of their life by attending the presentation; certainly, a feeling of defeat and not of conquest.

The final level of pleasure is the level of contemplation. In this level, the audience should be invited to reflect on what they have just learned for further contemplation even beyond the presentation. Having just successfully "conquered" the presented material, they are now empowered to make what they have learned their own through contemplation of the material. In some sense, this is what a question and answer session after a presentation should be about. Audience members earnestly proposing questions to the presenter which are a fruit of contemplating the presentation. This is facilitated by the presentation directly inviting the audience to contemplation by proposing future areas of work or highlighting what new questions have been raised in the course of the study. Alternatively, the conclusions reached in the presentation may have such an impact on the audience so as to inspire a change within them. Having now learned what was just presented, they can never be the same. Even better than the question and answer session, is for an audience member to approach the presenter later in the conference (or beyond) and say "I've been thinking about your presentation ever since I heard it" or "I can't stop thinking about _" or "have you ever thought of _". That indeed would be the sign of a beautiful presentation – that the perceiver has been forever changed for the better. Beauty, it is said, inspires us, moves us, and changes us. Scientists, most of all, should be amenable to this change and to contemplation at large. Good scientists are naturally formed in the ways of contemplation, as they are trained to sit, stare, think, ponder, question, and engage the world around them. It is one of the few professions in which you are expected, from time to time, to sit and do nothing other than to contemplate. It is for this reason that this author believes there is a fertile ground for the growth of beauty within the fields of science.

Conclusion

An intellectual framework with which to objectively assess and analyze beauty has been reviewed. Emphasis was given to relate the principles discussed to applications in the sciences. Many commonalities and points of similarity between the scientific framework and the classical understanding of beauty were highlighted. Several practical examples by which to better understand the classical framework were given. To summarize, beauty can be understood in the following way:

- Beauty inspires a movement of the perceiver's will towards the beautiful object of its perception. For this reason, it is beneficial to understand how to make science more beautiful so as to attract the wills of peers, funders, the public, and students to it. If for no other reason, scientific works should be made beautiful simply for the sake of its own good.

- Beauty was firstly described as a transcendental property of being. Along with truth and goodness it is an essential property of what it means for a thing to be. As such, beauty itself, insomuch as it exists, can also has the property of being true and good. The chief aim

of science is the pursuit of truth, usually for the good of humankind. For this reason, beauty (that which is true and good) is naturally affiliated with science (that which is concerned with truth and goodness).

- Since the beauty of a thing is dependent upon the truth about what a thing is, it is necessary to know what the nature of that thing is. Scientific principles were deployed to understand how we come to know the nature of a thing, and by knowing its nature make a judgment about its beauty.

- Once the truth about what a thing is (or should be) is known, an assessment can be made to determine if the exterior observances of that thing truly signify what it is to the perceiver. A beautiful thing is radiant with the truth of what it is. Beauty relieves the mind from the arduous task of determining what something is and simply reveals that truth to us straightaway.

- There are three attributes which communicate beauty to us and which must be present together in harmony for a thing to be beautiful: integrity, clarity, and proportion. All three attributes work in harmony to make a thing more beautiful.

- A beautiful thing is beautiful in and of itself regardless of how it is perceived. A beautiful thing is pleasant to behold and pleases the beholder. A more beautiful thing pleases the higher functions of the soul, with contemplation being the highest.

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Musical Aesthetics of the Natural World:
Two Modern Compositional Approaches

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Throughout recorded human history, experiences and observations of the natural world have inspired the arts. Within the sonic arts, evocations of nature permeate a wide variety of acoustic and electronic composition strategies. These strategies artistically investigate diverse attributes of nature: tranquility, turbulence, abundance, scarcity, complexity, and purity, to name but a few. Within the 20th century, new technologies to understand these attributes, including media recording and scientific analysis, were developed. These technologies allow music composition strategies to go beyond mere evocation and to allow for the construction of musical works that engage explicit models of nature (what has been called 'biologically inspired music'). This paper explores two such deployments of these 'natural sound models' within music and music generation systems created by the authors: an electroacoustic composition using data derived from multi-channel recordings of forest insects (Luna-Mega) and an electronic music generation system that extracts musical events from the different layers of natural soundscapes, in particular oyster reef soundscapes (Stine). Together these works engage a diverse array of extra-musical disciplines: environmental science, acoustic ecology, entomology, and computer science. The works are contextualized with a brief history of natural sound models from pre-antiquity to the present in addition to reflections on the uses of technology within these projects and the potential experiences of audiences listening to these works.

"Great art picks up where nature ends." - Mark Chagall

The natural world has been a focal point for the arts since the Upper Paleolithic. From the early animal painting in the cave of Lubang Jeriji Saléh on the Indonesian island of Borneo to the hyperrealist art in the 20th century, we can see countless examples of representations of life and landscape. For millennia, the natural world has been an unlimited source of aesthetic value, and one in which artists have found a key to beauty. However, since the advent of reproduction technologies (photography, recording technology) and sciences that enable quantitative understanding and simulation of natural environments, there has been a shift in the aesthetics of nature model-based art. Beauty has become a byproduct –not the goal– in the contemporary pursuit of modeling the aesthetics of nature. Jonathan Crary, in his book Techniques of the Observer, argues that "historical transformations in ideas about vision were inseparable from a larger reshaping of subjectivity that concerned not optical experiences but processes of modernization and rationalization" (Crary, 2001). This re-identification of beauty and aesthetics towards a more quantitative awareness of how the natural world functions and evolves is present within a 21st century strain of music composition practices for both acoustic and electroacoustic[1] forces. To contextualize and exemplify the diverse strategies of music composition that engage quantitative representations of the natural world, the authors first briefly trace historical uses of the natural world within music, from pre-antiquity to the present. Next, original work that each of the authors have derived from their respective doctoral research on natural sound and system models is presented and analyzed. While both of these projects engage quantitative representations of the natural world and technology-assisted analysis, each also differs in significant ways, offering two points on the wide spectrum of natural sound model composition strategies. Through the incorporation of essential properties of the natural world and human perception in these works, two questions arise: can sonic embodiments of essential attributes of the natural world, such as chaos and asymmetrical distributions, be viewed as 'beautiful'? How can uses of sound analysis technology and methods borrowed from environmental science impact compositional aesthetics? Through an interdisciplinary approach, both authors explore and find answers to these questions. On

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[1]Incorporating loudspeakers as a sound source.

one hand, environmental sciences and acoustic ecology[2] are at the core of Stine's work and provide a structural foundation for sonic data parsing in Acoustrans. On the other hand, entomology[3] and acoustic ecology provide essential information for the sound models from which Luna-Mega derives the melodic content of the reed quintet in Night Music.

Historical Musical Uses of Natural Models

The history of applied musical engagements with the relationship between sound and the environment is rich and lengthy. Classical examples include: the Ancient Greek 'Harmony of the Spheres', a description of the harmonious musical proportions of the planets; a creation story in the Vedic Sanskrit texts that takes sound as fundamental; and various other archaic 'acoustemologies' (sonic ways of knowing the world)(Feld, 1993). Other historical examples of musical predecessors that engage with translating the sounds of the world into the musical style of their time and place include: the Mongolian and Ouzbek galloping horse rhythms; VII B.C. Lydian poet Alcman's choriambic rhythmic cell based on an irregular succession of long and short accents (- u u -), similar to the cackle of the red partridge (alectoris rufa); and Notker of Saint-Gall's medieval motif inspired by the monotonous noise of a watermill in his sequence Sancti spiritus adsit nobis gratia (Mâche & Mâche, 1992).

Within the canon of notated Western music, imitations of animals (both in character and through their vocalizations) and natural events (rain, thunder, wind, etc.) begin to appear within the 14th century. These include examples in the works of Medieval and Renaissance composers such as Josquin des Prez, Clement Janequin, and Pierre Passereau. Des Prez's El grillo (The Cricket) is a choral work based upon a poem of the same name that playfully mirrors the subject matter of the poem through a musical strategy called 'text painting,' wherein gestures within the music (specifically repeated 'chirps' produced by the choir) musically reference mentions of the cricket in the text being sung. Another example is found in Janequin's Le Chant des Oiseaux, which includes cacophonous percussive sections, reminiscent of the sound of a flock of birds (Doolittle, 2008). Uses of animal sounds within these works do not deviate from the strict bounds of the musical structure: animalistic evocations are subsumed into the melodic, harmonic, and rhythmic rules of the time and reinforced through textual contextualization. During the 17th century, barring a few uses of comical incorporations of animal sounds in the works of composers such as Heinrich Biber and Georg Philpp Telemann, there are much less animal sound-incorporating compositions. Engagement with images and sounds of nature and animals are reinvigorated as tonality takes hold at the end of the 18th century.

Considering the broad historical span of the tonal era in the history of music, the list of examples of natural models

in this musical era is considerably large. In this overview we limit the contents to a succinct selection, largely based on Jennifer Goodenberger's Subject Guide to Classical Instrumental Music (Goodenberger, 1989). In the Baroque period, Vivaldi's famous The Four Seasons features a diversity of birds in the Spring movement, as well as a representation of the motion of snow in the strings' descending pizzicati in the Winter movement. The same composer uses the cuckoo as a sound model for a section of his Violin Concerto in A RV 335. Handel's Concerto for Organ in F Major MWV 295 "The Cuckoo and the Nightingale" features transformations of the cuckoo's song into repetitive ostinato lines that serve as counterpoint for the organ polyphony. Birds, especially the cuckoo, are widely featured throughout the Classical period. Some pieces include Leopold Mozart's Toy Symphony (cuckoo), Haydn's Quartet for Strings Op. 65 No. 5, "The Lark", and Symphony 83 in G minor, "The Hen", which features a timbral transformation of the hen's repetitive ternary rhythmic pattern in different instrumental groups of the orchestra, from the woodwinds to the strings. In the Romantic period, a more widely known example is Beethoven's Symphony no. 6 "Pastorale". In the last section of the second movement, a nightingale, a quail and a cuckoo are featured by the woodwinds; in the fourth movement, a storm is powerfully portrayed with the full orchestral forces, including the timpani's subito forte attacks representing thunder. Debussy, one of the composers who began drifting from Tonality, is characteristic for the use of geophonic sound models in his music: included in his Preludes for piano, no. 3, "The wind in the plain", is a virtuosic depiction of sudden and occasionally violent gusts of wind. In La Mer, at the turn of the twentieth century, Debussy uses different states of the ocean as a sound models for one of the most praised orchestrations in history.

More modern, applied instrumental music examples (post-tonality) include John Cage's Atlas Eclipticalis, a work that makes use of star charts to inform the structure of a composition, the musical settings of bird calls in the work of Olivier Messiaen, and the millimetrization technique of Schillinger, all of which seek to map natural environments outside of the concert hall onto instrumental music (Stine, 2019a). The musical composition techniques of spectralism, which take as musical material and organizing principle structures derived from specific sound recordings or acoustical phenomena more generally, may also be seen as engaging hyper-specific natural sound models. For example, the opening material of spectralist composer Ge´rard Grisey's chamber ensemble work Partiels is derived from a sonogram analysis of a recording of a low E on a trombone, approximated

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[2]Acoustic ecology is the relationship, mediated through sound, between human beings and their environment (Wrightson, 2000)

[3]Entomology is the branch of zoology that studies insects.

within the ensemble to the nearest quarter tone (Fineberg, 2000).

Similarly, the work of zoomusicologist Francois Bernard-Mâche expands outwards from instrumental music representations of birdsong to other animal vocalizations and sounds of natural phenomenon: rain, thunder, avalanche, etc., mapping to musical contexts a variety of natural system sound recordings and experiences. Other examples include Bartok's Out of Doors suite for piano (1926), which includes a movement that imitates the sounds of a Hungarian summer night, as well as some of George Crumb's work, including Vox Balaenae ('Voice of the Whale') for electric flute, cello and amplified piano (1971) where both the name of the work and its sound worlds evoke the world's largest animal.

Engagements with nature as a source of musical expression are not limited to purely acoustic forces, and there are a significant number of engagements with technology over the past 50 years that have incorporated sounds, data, and simulations of the natural world. Examples include Gordon Mumma's Mograph series, which takes as sonic material seismological data, along with computer assisted, natural world data-driven works such as John Luther Adam's The Place Where You Go To Listen, which uses meteorological, seismological, and other natural data sources to generate real-time electronic music. Electronic music composers such as Natasha Barrett and Hans Tutshku have use of models of natural systems (notably geological and hydrological systems, including avalanches) to generate sound materials and dictate musical structures used within their electronic works. In a more exploratory vein, the experiments of Thomas Shannon and John Lifton in the 1960s amplified the sounds of living plants through electric pickups. This practice has been updated with digital technologies in the work of Mileece Petre, among others, who maps the electromagnetic current of plants to musical notes using custom software, and with MIDI Sprout, a portable plant-to-instrument note sound mapper crowdfunded in 2014. As a last example (again, of a significantly large field), the activity of animals is electroacoustically amplified in Ce´leste Boursier-Mougenot's from here to ear (v.15), an installation which places 14 differently tuned electric guitars within a makeshift aviary containing 70 zebra finches, whose landings and peckings on the instruments are electronically amplified (Stine, 2019b).

Author's Works

AcousTrans and Night music are contemporary examples of the historical continuum described above. While sharing the same foundation –the derivation of musical features from the natural world with a strong emphasis on the spatial immersion of the listener– the materials and procedures they employ come from two substantially different sound worlds: the acousmatic and the electroacoustic. While AcousTrans is a system that produces acousmatic music, characterized by

the use of loudspeakers as its sole medium for the transmission of electronically produced or processed sounds, Night music is electroacoustic, combining electronic media with acoustic sources (i.e., musical instruments). These differences between both pieces results in a complementarity that brings together powerful tools of the computer sciences and concert music in the translation of the aesthetics of the natural world into music. Music Information Retrieval (MIR), a field of computer science whose goals include processing and calculating large amounts of sound data, provides invaluable tools for analyzing sounds found in natural environments and mapping them onto musical parameters. In this way, AcousTrans opens a field of possibilities for creating music that shares organizational features with a natural soundscape. On the other hand, Night music approaches the complexities of entomological sonic data with the purpose of its translation to music notation for human performance. The objective is the embodiment of nature's sonic world in the composition, performance and audience domains. In this way, AcousTrans and Night music constitute two specific and diverse approaches to the analysis and aesthetic applications of natural sound. The former takes an oyster reef as a sound model whose end result is an acousmatic spatial immersion; the latter uses stridulating[4] insect sounds as models for musically notated electroacoustic spatial immersion.

Night music

Night music is a piece for reed quintet (oboe, clarinet in Bb, alto saxophone, bass clarinet and bassoon) derived from direct transcriptions and arrangements of a 5-channel recording of the summer dusk and night sounds of stridulating insects in a Virginia forest. The piece is structured in five movements, each taken from a fragment from the 40-minute original recording. The striking increase in harmonic density and loudness as dusk becomes night is the guiding formal principle of the piece. The recordings, featured in the electronics, were made with five simultaneous microphones in a pentagonal distribution, at a distance of 30 meters between each mic. Each of the five microphone analyses and transcriptions was assigned to an instrument. The multi-channel recording sought an expanded listening field resulting from the different microphone responses and placings. Like most of the author's work, this piece translates quantifiable sonic data from nature –in this particular case, summer dusk insect sounds in deciduous forests of North America's east coast– into notated music for performers. The main goal is the human embodiment of natural aesthetics via sound.

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[4]Stridulation refers to the production of sound by rubbing one body part against another.

⑥③① Old Lynchburg Rd	3.15	**800**		G		97%	1%	1%	1%	0%	0%	F	0.140	0.613	830	G	2016

Figure 1. Annual Average Daily Traffic chart (Virginia Department of Transportation)

Figure 2. Map of Walnut Creek Park microphone setup location (each side of the pentagon is 30 meters), and corresponding concert loudspeaker configuration.

Field Recording

Background noise and location. The recording was realized in the Walnut Creek Park, situated in the North Garden unincorporated community in Albemarle County, Virginia. The location was decided based on data obtained from the Virginia Department of Transportation's AADT (Annual Average Daily Traffic) information Virginiaroads.org (2019). This document provided useful information to avoid areas with high noise pollution derived from ground and air transportation. The average ADT in the nearest roads to the park is 1,300, of which 65% of the traffic volume travels in the peak hour. In comparison, other parks within this area of Virginia are situated near roads with an ADT of 52,000. For field recordings that will provide sound models for composition, this consideration is essential.

Spatialization: expanded auditory and perceptual fields. Five rigs with microphones of various specifications were placed around an imaginary pentagon of 30 meter sides. Varying microphones were used instead of matched microphones in order to compositionally explore the variances between the sound perceived by each microphone. Such perceptual variances consist of subtle differences in pitch, which derive the harmonic content of the piece. There were two objectives in the realization of the spatialized field recordings and the resulting sound model-derived piece: 1. Capturing the constantly shifting sound of the cicadas throughout the recorded perimeter. A by-product of this goal was an expanded auditory field, comparable to a 360° photo, where the perceived sonic events are distributed throughout the perimeter. 2. Continuing research on the various modes of perception and compositional implications, which has been present both in the author's creative compositional and analytic work. Night music explores the different contents that each microphone and recording device captured of the same environment. These varying perceptions integrated within the same system result in an expanded perceptual field. The spatial distribution of the field recording is recreated in the performer setup for the live performance of the piece. The performers surround the audience in an imaginary pentagon distribution.

Sound models

There are several types of events in the summer dusk recording. A selection of these were used as sound models that were transcribed, analyzed and orchestrated for the reed quintet. The sound models are the following:

1. Rhythmic bursts versus continuum The recording scheduled day was around 10° F cooler than the average 86° F in the area in August. Humidity dropped considerably, which resulted in a significant change in the sound production of the cicadas. The rate of repetition and length of

the cicadas' echemes[5] was considerably lower than on days in which temperature and humidity were higher. Instead of generating sweeps of sound masses around the audible perimeter, the cicadas produced groups of three to four brief echemes per second which, multiplied and scattered throughout the perimeter, produced a cacophonous sonic glitter that provided the direction and form of the piece.

In Figure 3, the different iterations of the 3-4 echemes sets are presented simultaneously in the five channels of recording. This multiplicity in the periodicity of each of the channels results in effective material for a spatial/surround display of the sound.
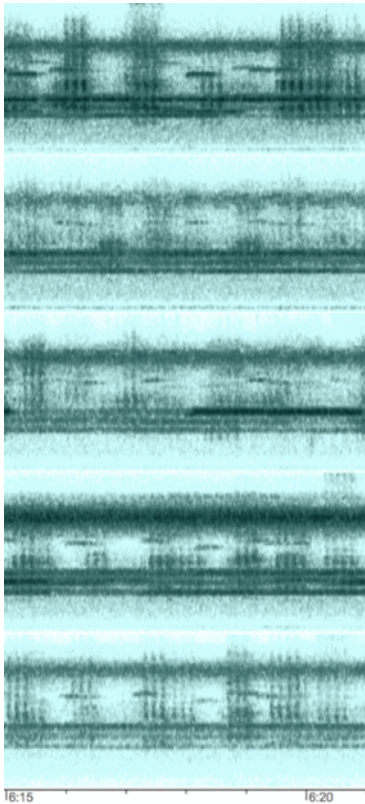

Figure 3. Groups of 3 to 4 echemes in 5 channels

2. Echemes gradual saturation One of the most striking features of the soundscape of stridulating insects and cicadas in seasons of hot climate is the gradual increase of sound activity that takes place at dusk. The density and loudness of the recording changed dramatically from its beginning (at 7:30 pm) to its end (8:10 pm). The way in which the gradual saturation takes place in the course of 40 minutes is seamless, without discontinuities in intensity, always filling the acoustic space and time by means of short steps. From a sound-model perspective –translating the sonic parameters of this dusk soundscape into a composition–, the gradual increase of acoustic energy is fertile ground for music composition. Regardless of the fact that the formal direction itself is not new –various pieces from the last two centuries display a

gradual increase in energy towards a climactic ending–, the way in which a limited number of relatively simple musical materials accumulate so gradually in a multiplicity of periodicities elicits relevant experiments in conceiving the temporal domain. In Figures 4 - 6, varying degrees of saturation of the sets of echemes are shown in three different successive moments in time. In the Figure 4, the black vertical brackets highlight the iterations of the echemes. Note the contrasting spacing of the echemes between the beginning 30 seconds (from 1220" to 1250") and the last 20 seconds (1300" to 1320") of the first example.

In Figures 5 - 6, the saturation is considerably higher, not only in the rate of repetition of the echemes, but also across the frequency bands.

3. Stridulating tunings (cricket chorus) Another important signature of the field recording is the crickets' stridulation producing a harmony very similar to the major triad. The relative pitches that form the triad, common in most music in the world, are present in all harmonic sounds in the physical world. A striking particularity of the triad produced by the cricket chorus is the subtle variation between the pitches included in it. This slight variation in each of the three pitches creates a sonically and compositionally compelling clustering around each of the pitches. The complexity of the multiple iterations of sounds tuned at and slightly around the triad's pitches is one of the most explored aspects in Night music. In Figure 7, the three pitches in the triad are displayed. The thickness of the lines show the clustering of pitches around the main pitches in the triad.

4. Microphones' perceptual variations of the same source As mentioned in the "Field Recording" section above, a striking finding in the spectrum/sonogram analyses of each of the 5 microphone recordings was that when two or more microphones presented the same sonic event, there were subtle variations in the tuning of the event. The two main factors for these variations are: 1) location and 2) frequency response. With regards to the former, considering that a space behaves like a filter that amplifies and attenuates certain frequencies, a specific forest location filters the sound differently than another forest location. In the case of the latter, each microphone picks up a different range of frequencies, which will yield subtle differences when one sound is recorded by two or more different microphones.

The sonograms in Figure 8 present the same sonic information in two different microphones (mics. 4 and 5). The stridulation analyzed is displayed by a rectangle. The horizontal line displays the pitch with the highest intensity in the stridulation, which determines the perceived pitch. The loudest frequencies in both microphones differ by 40 Hz, which in that pitch region results in a distance of 1/8 of a tone.

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[5]An echeme is essentially an uninterrupted burst of sound, which can be as short as a tick or a click or it may continue for a longer period (Popple, 2006).
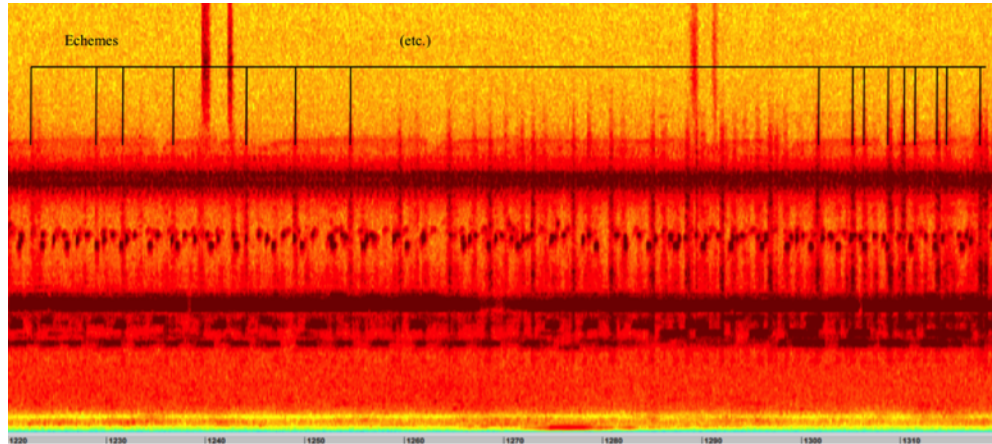
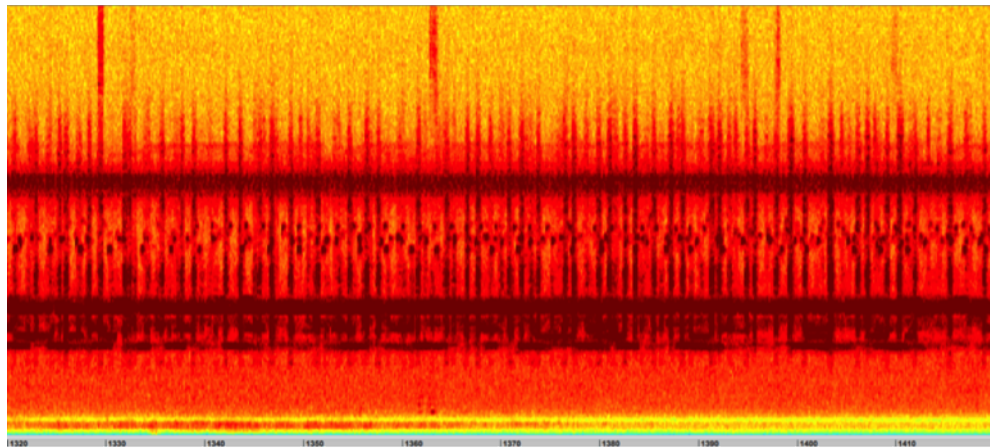*Figure 4*. Gradual saturation of echemes (low saturation)

Figure 5. Gradual saturation of echemes (medium saturation)

To put this in perspective, the smallest division of the tone in the concert music tradition is 1/2 of a tone (the distance between a white key and a black key in the piano). This is a considerably subtle difference in the pitch content of each microphone. Used as sound models for the pitches assigned to the reed quintet, these micro-variations resulted in a harmonic complexity that translated some of the sonic features of the original stridulating sounds resonating spatially in the forest.

Performance

Night music was premiered by Splinter Reeds on February 1st, 2019 at the University of Virginia's Old Cabell Hall. The five performers were distributed in an imaginary pentagon surrounding the audience, recreating the microphone distribution used in the summer dusk recordings. Next to each performer was a speaker, amplifying the performers sound and playing fragments of the original recordings. The activity of the performers and the presence of the original recordings increased gradually towards the end of the piece, which consists of a full spectrum of cacophony

blending the pitch and noise worlds, as it happens in deciduous forest summer dusks in the North American east coast. For recording, program notes and score, please visit: *http://www.christopherlunamega.com/works/compositions/night-music-composition*

AcousTrans

The Eastern Oyster (crassotrea virginica) is an essential part of the Eastern coast of the United States, filtering the water column and vastly improving water quality (Coen et al., 2007). Eastern Oyster populations on the Virginia coast and in the Chesapeake Bay have declined to approximately 1% of pre-1900 levels, and they are currently a major focus of restoration efforts by The Nature Conservancy (TNC) at the Virginia Coast Reserve (VCR) (Kemp et al., 2005).

During the summer of 2018, Stine was in residence at the Anheuser-Busch Coastal Research Center, the site of the Virginia Coastal Reserve's (VCR) Long-Term Ecological Research (LTER) station. During this residency, the author collaborated with environmental science Ph.D. candidate Martin Volaric to study oyster reefs using an unlikely technology:
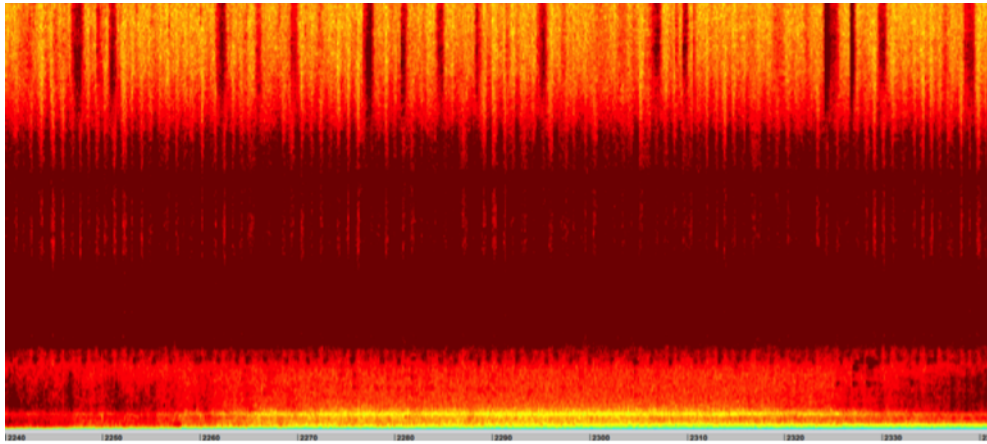
Figure 6. Gradual saturation of echemes (high saturation)
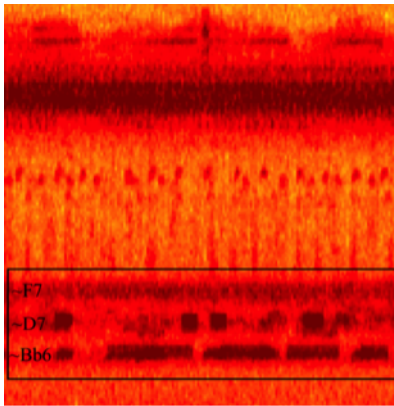

Figure 7. Gradual saturation of echemes (high saturation)

sound recording equipment. Bioacoustic monitoring, the recording and analysis of the acoustic emissions of animals, has been used in the study of behaviors and to aid in census counts of many species of animals, including birds, wolves, and marine animals. The marine animals observed using this technique include marine mammals, fish, crustaceans, and marine habitats more generally. The excellent propagation properties of sound waves in the water combined with the fact that many marine organisms produce sounds, intentionally for communication or remote sensing, or unintentionally each time they move, makes acoustic monitoring a powerful method for recording animal behavior.

The goal of the author's and Volaric's research was to compare bioacoustic monitoring measures to the marine biologist's more traditional non-acoustic measures (which include oxygen production, water speed, and turbulence), and to see if there is a correlation between one or more of the parameters measured by each.

To accomplish this, over the course of 4 weeks the author and Volaric recorded over 180 hours of two oyster reefs using two hydrophones (underwater microphones). After collect-

ing this data, the author and Volaric worked collaboratively to deploy methodologies for extracting information from the sound data and relating them to the non-sound data. First, the author applied heuristics used in the context of Music Information Retrieval (MIR) and bioacoustics, the results of which included time series data that ranged from the general (zero crossing rate, energy, spectral centroid) to the highly-specific (biodiversity indices developed for rain forest acoustic analysis). While these heuristics were able to be synchronized with the non-sound data and significant correlations were able to be shown, they were not able to indicate information specifically related to the Eastern oyster.

This was primarily because of a single animal: the most dominant feature in all sound recordings made of the reef is of snapping shrimp (alpheus heterochaelis), often called pistol shrimp, who use the fast and powerful closing of their large claws (which causes a cavitation bubble) to stun prey. This activity embodies itself in recordings as a dense, cacophonous chorus of wide-band, noisy explosions, exactly the type of chaotic texture that masks other sounds in the soundscape, what could be referred to as 'noise' in this context. A different approach needed to be made, then, one that either filtered out the sound of the snapping shrimp or sidestepped it entirely by honing in on the sounds of the oysters.

Krause's Niche Hypothesis

The Niche Hypothesis was developed in the early 1990s within the area of acoustic ecology by acoustician Bernie Krause (Krause, 1993). This hypothesis states that in an unfettered landscape the communicative sounds of different animals naturally situate themselves within exclusively different ranges of the frequency domain. For example, orangutans might vocalize at low frequencies, birds might vocalize at higher frequencies, insects at still higher frequencies, and bats at frequency ranges above the threshold of human hearing (the supersonic range). Within the intertidal oyster reef
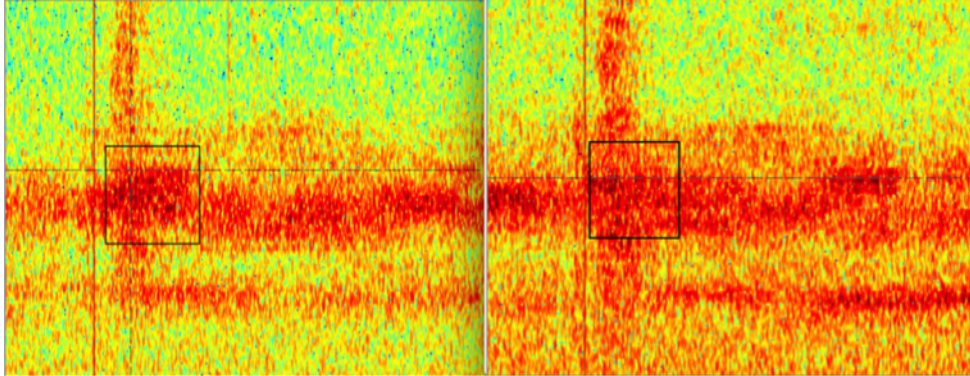
Figure 8. Same sonic information in two microphones. 2580 hz (rounded to D) / 2539 hz (rounded to D)

Figure 9. Night music, first 10 seconds of movement 4 (approaching the highest degree of saturation of the field recording)

the sound of the water turbulence, the vocalizations of fish, the sound of oysters, and the sound of shrimp snapping are all stratified in a similar way, following Krause's hypothesis.

The fact that the oyster reef soundscape is stratified in such a way was very impactful to the author's research, allowing the sounds of the snapping shrimp to be filtered out entirely and the quiet-but bounded within a specific, known frequency band-sounds of the oysters to be isolated. Ultimately, the author and Volaric determined that using a technique called acoustic event detection, a time series of oyster clicks over the course of the reef recordings could be produced. This time series data could then be synchronized to the non-acoustic data. From this, the author then showed that the amount of oyster clicks every 15 minutes had a significant correlation to the amount of oxygen produced by the reef, suggesting that hydrophones and bioacoustic monitoring measures more generally could be a potential alternative to the much more expensive oxygen monitoring equipment. This work has been presented internationally and as of this writing is being drafted into an article for publication in a marine science journal.

Musical Application of the Niche Hypothesis: Acous-Trans

Engaging with the Niche Hypothesis within a scientific context led the author to wonder in what ways this hypothesis could be applied to the task of making electronic music. The application decided on and implemented by the author is the software AcousTrans. The goal of AcousTrans (Acousmatic Translator) is to allow a user to load in a source stereo audio file (field recording or other environmental recording) and a destination corpus of other audio files and interactively map the events, gestures, and structure of the source onto the destination. What results is a stereo or surround sound[6] audio file with gestural, rhythmic, and/or structural similarities

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[6]Multiple channels of sound places around the listener to immerse then in a 360º sound field.
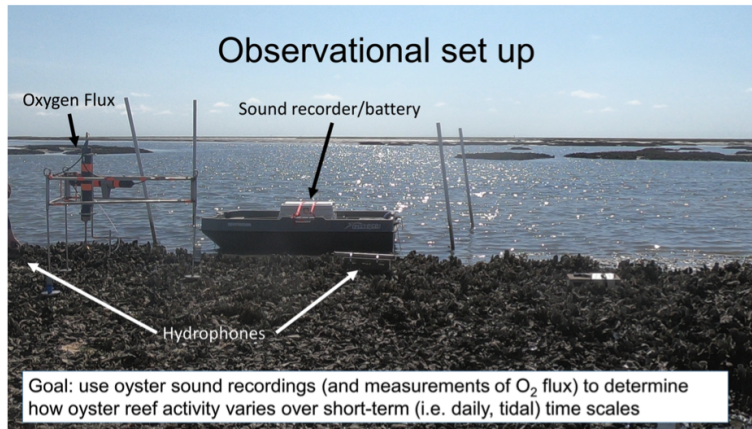
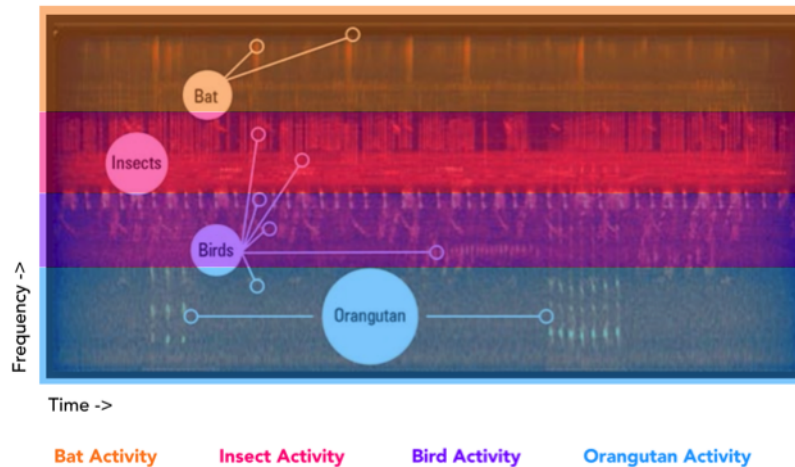*Figure 10.* Bioacoustic Monitoring Observational Setup

Figure 11. Visualization of Krause's Acoustical Niche Hypothesis

to the source file (the natural environment), but with entirely different musical characteristics: those of the destination corpus. Delineating this process more explicitly, the application of the Niche Hypothesis in AcousTrans is as follows:

1. Deconstruct a soundscape recording into different frequency ranges (low, medium, or high pitches, and all of the minute gradations therein), ranges which separate out the different living and non-living sound production sources

2. Extract events from each band, assuming that these events may be ascribed to the different sound production sources, and therefore that they act as sonic surrogates of multi-layered environmental (inter)activity

3. Use these events to trigger different sounds (in multichannel sound space), effectively translating the activity of an environment into a different musical context, one where gesture, rhythm, and other musical parameters, are dictated by environmental activity.

Figure 12 presents an image of the interface of the software programmed to accomplish the first and second steps of this process: loading in a recording (for example, the oyster reef), dividing it up into different scientifically determined frequency bands, and then using a segmentation algorithm to extract different events (oyster clicks, snapping shrimp clicks, boat passes, etc.).

Composing with AcousTrans

To accomplish the third step in the process outlined, the author created an event mapping software (Figure 13) that gives a composer lots of freedom for creating music with this technique. The events of the source environmental soundscape can be mapped to different audio files manually or through acoustical analysis. The intensity, spatialization, and speed of sounds produced from the destination corpus can also be manually set or driven by the events in the environmental soundscape. In addition, a wide variety of different sound processing effects -such as echo, filtering, and stuttering- may be dynamically applied to the generated sound world, offering a vast set of electronic music composition gestures and textures.
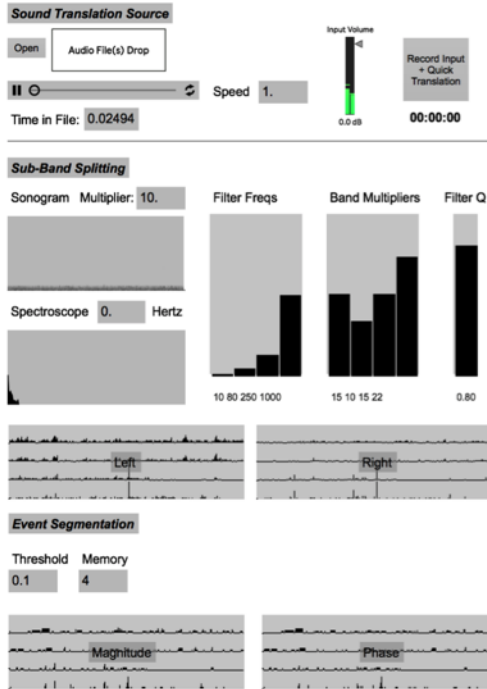
Figure 12. AcousTrans Segmentation and Event Extraction Module

Figure 13. AcousTrans Playback and Effects Module

The output of AcousTrans is multi-channel electroacoustic sound which, when played back over a multi-channel loudspeaker (most often experienced via surround sound speaker environments within movie theaters) is immersive electronic music derived from the activity of a natural environment.

AcousTrans is implemented in Cycling '74's Max 8, taking advantage of ICST's Ambisonics externals to handle multi-channel audio and IRCAM's MuBu for Max and Programming Interface for Processing Objects (PIPO) Max externals to handle acoustic feature analysis.

Conclusion

AcousTrans presents a methodology for intelligently mapping a multi- dimensional stream of gestures from one environmental soundscape to an entirely different, multi-channel electroacoustic sound world. Being derived from the scientific application of an acoustic ecology concept, this software harnesses techniques from both bioacoustics and MIR to facilitate the generation of electroacoustic material derived from the activity of natural environments. From a poetic standpoint, this system points towards the agency of the environment (of its interactions, its inhabitants, and its chaotic qualities) as a musical force, demonstrating the expressive beauty of our natural world through translations of its activity
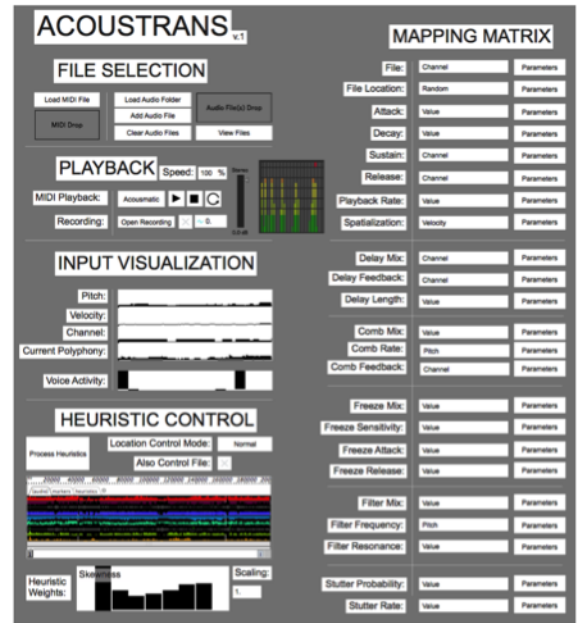
to novel sound worlds. Examples of the AcousTrans in action may be heard at: *www.elistine.com/software/acoustrans*.

Discussion

Reflection on Uses of Technology

Technological advances and the field of music are deeply connected; methods of organizing sound (tonality, serialism, spectralism) may be considered types of technologies. Within the pre-compositional and compositional phases of both of these works, digital technologies (in the form of software run on computers) act as assistant, translator, and can even have their own compositional voices. More explicitly, the analysis process of Night music involves the use of AudioSculpt, a program which outputs spectrograms, visualizations of sound. In conjunction with the composer's eyes, these spectrograms allow for an understanding of the components within a particular sound that might not be possible with the ear alone. Additionally, hyper-sensitive frequency analysis tools are used to analyze the utterances of insects using the language of music: pitch, frequency, and timbre. This then allows such utterances to be translated to a musical language (notation) which can then be interpreted and performed by instrumentalists. Each of these technological assistants (spectrography and frequency analysis) aid the composer in being able to musically deploy the complexity, the detail, the intense richness and beauty of natural sound, in this case recordings of insect calls at dusk.

In contrast, AcousTrans is a technology in and of itself, one that is an application of the Acoustical Niche Hypothe-
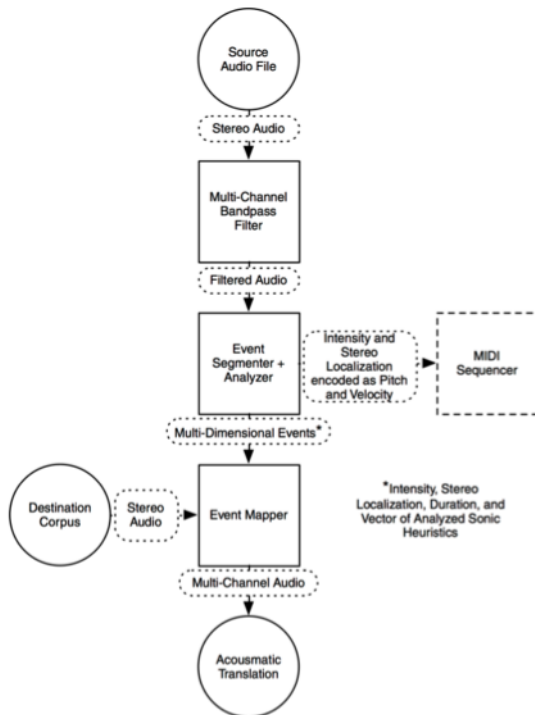
Figure 14. Systemic Diagram of AcousTrans

sis. The Acoustical Niche Hypothesis comes from the acoustic ecology subfield of environmental science. The application of the Hypothesis within AcousTrans is translational and productive, harnessing this Hypothesis as a technology to not only deconstruct a soundscape but to map the events born from that deconstruction onto an entirely different sound world. The purpose of this technology is to be able to utilize the tempos, the rhythms, the calls and responses, the ecosystemic activity of environments (through recordings of soundscapes) within the composition of electronic music. Here the translation is from recordings of natural environments to new musical settings of the activity of those natural environments, using natural systems as complex, black box algorithms to produce immersive musical experiences.

Reflection on Musical Results

Like all things musical, the end results of these projects are best understood through their sensuous sonic reception by the audience. The experience of listening to Night music is multi-layered. The sounds of the instruments, the sounds emanating from the speakers, the experience of being engulfed within the recognizable, but still alien world of a chorus of insects during dusk within the concert hall, all commingle to create an experience of this work. An exceptional moment within the piece comes at its end, when the choir of insects reaches its apex, overwhelming the audience in sheets

of sound, while the instrumentalists contribute to the texture. Electronic music produced with AcousTrans, like Night music, explores musical experiences of sonic environment where rhythm, pitch, and melody are re-evaluated. In particular, with the output of AcousTrans being played back within a multi-channel loudspeaker context, one has the sense of being surrounded by living things, sonic animals that are triggered by certain events, which then interact, the sonic residue of which is the music of the piece. Rhythm and tempo, then, are solely byproducts of interactivity between the different agents of the original soundscape.

Conclusion

This article explores two modern, environment-conscious strategies for the creation of musical experience, what could both be described as 'natural model musics'. These works are musical settings of natural events: the sounds of insects within the work of Luna-Mega and the sounds of oyster reefs within the work of Stine. During the pre-compositional and compositional processes for these works, resources, theories, and viewpoints of environmental science are engaged with, which contribute to an overall aesthetic that positions the experience of natural environments (sonic or otherwise) as a major driving factor of musical experience, supplementing - or potentially suggesting a redefinition to- more traditional musical experiences that foreground more traditional features of music (melody, harmony, steady rhythm). For both authors, this redefinition of musical experience as one that is deeply, quantitatively connected to the experience of natural environments is for the purpose of attaining a particular natural world aesthetic, harnessing the beauty that is present within such natural environments, touching some part of the sublime that is found in the simultaneous complexity, simplicity, and profundity of the natural world, that might not be possible to engage with in any other way.

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