THE BEAUTIFUL AND THE SUBLIME IN NATURAL SCIENCE

by Peter K. Walhout

Abstract. The various aesthetic phenomena found repeatedly in the scientific enterprise stem from the role of God as artist. If the Creator is an artist, how and why natural scientists study the divine art work can be understood using theological aesthetics and the philosophy of art. The aesthetic phenomena considered here are as follows. First, science reveals beauty and the sublime in natural phenomena. Second, science discovers beauty and the sublime in the theories that are developed to explain natural phenomena. Third, the search for beauty often guides scientists in their work. Fourth, where beauty is perceived, feelings of the sublime often also follow upon further contemplation. This linkage of beauty in science with truth and the sublime runs counter to most aesthetic theory since Kant. Scholarship in theological aesthetics has recently argued that the modern and postmodern elevation of the sublime over beauty is merely a preference that reveals a bias against transcendence—against God. If doing and understanding science can show this sundering of the sublime from the beautiful to be in error, science also gives evidence of transcendence.

Keywords: aesthetics in science; art in science; art work; beautiful; beauty; beauty in science; general revelation; God as artist; mimesis; natural science; philosophy of science; sublime; sublime in science; scientist as artist; theological aesthetics; transcendence; wonder; work of art

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Ascribing aesthetic qualities to aspects of natural science and mathematics dates back at least to Aristotle, who wrote of the beautiful order and symmetry in mathematical relations (*Metaphysics* xiii.3.1078^{a}33-^{b}2). Many Nobel laureates have extolled the beauty found in scientific theories, including chemist Rudolph Marcus who remarked that "the beauty which a scientist can experience after deriving a simple equation or executing an incisive experiment is just as real as that which the artist may experience in

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creating a work of art" (1993). Others have found more sublime qualities in the uncanny way that abstract mathematical ideas end up being key descriptors of the physical world. This fittingness has been described by physicist Eugene Wigner as "the unreasonable effectiveness of mathematics" (1960).

The pervasive impulse on the part of scientists to invoke aesthetic language when reflecting on their work demands an explanation, but one that goes beyond what Nobel laureate physicist Steven Weinberg describes as "talk about the importance of beauty in science [that] has been little more than just gushing" (1992, 132). Indeed, serious philosophical work has started to come forth in recent years (see McAllister 1996; Wechsler 1978; Kuipers 2002; Deane-Drummond 2006; the latter is more theological). Although the beauty of natural phenomena newly discovered through scientific inquiry can be seen as an extension of creation's natural beauty long evident through the ages, other aesthetic aspects of science have no facile explanation. For instance, many scientists claim that a search for beautiful explanations guides their thinking and research. Why should this be? Is it simply a matter of semantics, with scientists conflating the terms *correct* and *beautiful*? It seems to be more than this, especially given the voluminous testimony of scientists to the aesthetic nature of their scientific life. There is not only a feeling of satisfaction that accompanies a correct solution but also an aesthetic experience akin to the contemplation of a great painting. Reading through Albert Einstein's derivation of the Planck radiation law based on the kinetics of absorption and emission of light is more than just an experience of triumph at seeing a valid derivation; it is in fact a thing of beauty.

For the theist, an explanation of beauty in science and more generally in the natural world obviously will be linked to the notion that beauty somehow reflects and derives from the divine beauty of the Creator. The alternative to invoking divinity in explaining the importance of beauty to humankind is resorting to a purely evolutionary explanation. The aesthetic nature of science is then not some divine reflection but an idea in human brains that has resulted, without divine input, from natural selection. As Weinberg put it, "our way of looking at the universe has gradually evolved through a natural selection of ideas. Through countless false starts, we have gotten it beaten into us that nature is a certain way, and we have grown to look at that way that nature is as beautiful" (1992, 158). Weinberg here describes not real natural selection at the genetic level but an analogy for a system of science education that presumably instills notions of scientific beauty. A truly evolutionary explanation of beauty in general must posit that at some point in human evolution those creatures that developed a sense of beauty were able to survive better than their nonaesthete competitors. Whether the naturally selected aesthetic advantage was linked to recognizing pastoral savannahs and puffy clouds as sources of food and water

or to lusting after the opposite sex as a prompt for gene propagation must remain largely speculative.[1] In any case, such purely evolutionary explanations of humanity's desire for beauty are deeply unsatisfying from a theistic perspective.

My broad goal in this essay is to introduce the notion that the aesthetics of science can be explained within the context of Christian theological aesthetics and that using aesthetics and the philosophy of art to discuss creation and science opens up a rich field of inquiry. New ideas in this area can easily draw upon and affect a wide range of established areas of thought and doctrine, including philosophical and theological aesthetics, general revelation and natural theology, modernism, postmodernism, realism and antirealism, religious experience, philosophy of science, quantum mechanics, cosmology, and creativity, among others. Given the relative paucity of philosophical work that systematically treats the wide variety of aesthetic phenomena in the scientific enterprise, it is not surprising that such work that also incorporates the insights of the Christian tradition of theological aesthetics is virtually nonexistent.

The specific purpose of this essay is to offer an exposition of a new idea generated by the aesthetic considerations cited above. The idea is this: God the Creator is an Artist, and therefore understanding how and why scientists study nature, God's artwork, can be aided by using the philosophy of art and theological aesthetics. In the first part I focus on the notion that God is an artist and scientists are both artists and art connoisseurs. The great scientists seek beauty and create beauty in science and rely on beauty as a signpost for truth because God's creative artwork is infused with beauty. The philosophy of art and aesthetics of Nicholas Wolterstorff supports these ideas. In the second part I examine experiences of the sublime in science. Although scientists and philosophers of science have discussed beauty in both popular and more serious works, there has been little mention of the sublime moments in science. This is surprising given the prominence of the sublime in postmodern philosophy and recent theology. Moreover, I argue that experiences of the sublime are what draw many individuals into the study and practice of science. Scientific discoveries and theories often are so surprising and intoxicatingly difficult to fathom that they occasion sublime experiences of universal appeal that leave one yearning for more. The thesis of the second part is that scientific experiences of the sublime are intimations of a transcendent reality, God the Artist. Specifically, I argue that in science experiences of the sublime often follow a judgment of beauty, and both are linked to scientific knowledge. This runs counter to most aesthetic theory since Immanuel Kant but is in line with recent attempts in several fields to "recover" beauty (see Steiner 2001; Danto 2003; Nehamas 2007). Theologians John Milbank (1998), John Betz (2005; 2006), and David Bentley Hart (2003) have argued that the modern and postmodern separation and elevation of the sublime over

beauty is merely a preference that reveals a bias against transcendence—against God. Doing and understanding science seems to corroborate this notion, as judgments of beauty and the sublime are not always separated and for many scientists lead to experiences of transcendence rather than intimations of a dreadful nothingness.

Part 1: Science and Art

God the Artist (Deus Artifex). God created the universe contingently, and the universe contains beauty, so God can be viewed as an artist. This is by no means a new theological thought, as the following examples attest. Thomas Aquinas compared God to an artist several times in the *Summa Theologica*. St. Bonaventure referred to the second person of the Trinity as the Eternal Art (*ars aeterna)*. St. Augustine speaks of the *Deus Artifex* fashioning beautiful bodies upon the resurrection. St. Basil invokes the title "Supreme Artist" to explain the creation verses "And God saw that it was good" (Genesis 1:10 ESV). St. Cyprian even manages to refer to "God the artificer" in arguing against female beautification: "That you think yourself to be adorned, that you think your hair to be dressed, is an assault upon the divine work, is a prevarication of the truth" (*Treatise II*, sec. 15).[2] The one caveat to the notion of God *qua* artist is that unlike a human artist, the *Deus Artifex* must also create the raw material for God's art work if creation *ex nihilo* (out of nothing) is to be upheld.

The appellation of Artist for God does not rely solely on a potentially controversial analogy of being (*anologia entis*), however, because God *qua* artist is a biblical concept as well. As Hart asserts, "The Bible . . . depicts creation at once as a kind of deliberative invention ('Let us make . . .') and, consequently, as a kind of play, a kind of artistry for the sake of artistry" (2003, 251). The "nature psalms," for example Psalms 19 and 111, speak unmistakably of a divine Artist, and the passage in Exodus regarding the tabernacle design that Moses received directly from God vividly portrays the notion of God *qua* artist (Exodus 35:30–33). The metaphor of God as a potter in Isaiah 64:8 is especially apt. A potter strives to make vessels that are both useful and beautiful: "And out of the ground the LORD God made to spring up every tree that is pleasant to the sight and good for food" (Genesis 2:9 ESV).

Philosophical descriptions of art and artistic creation often read like passages on the theology of creation and general revelation. The former is focused on artists, their consciousness, and their purpose, while the latter is concerned with knowledge of God, God's attributes, and God's role in our world. Take this passage from Wolterstorff and note how it could have as its subject either art or theology:

> We may speak of the work as an expression of the world behind it—meaning simply that the conviction and concerns belonging to that world account for the

> artist's making the work, and for his making it as he did. What must be added at once, however, to forestall misunderstanding, is that the work by no means always fully reveals the world behind it. Even the most perceptive apprehension of the work may leave us uninformed as to crucial elements in the world behind it. A work may be an expression of the world behind itself without fully revealing that world. (1980a, 89)

Although this passage is about the philosophy of art, we can see the common themes of general revelation: We can know of God by observing the world, but we cannot learn all there is to know about God simply by contemplating God's works.

Wolterstorff on Art and the Artist. If we see creation as art work, we should be able to learn something about science by studying art. In these sections I briefly examine Wolterstorff's philosophy of art and aesthetic theory (1980a, b). I use Wolterstorff not only because he writes from a Christian perspective but also because he espouses a representative theory of art that seems appropriate for the notion that God the Artist reveals something of God's self in creation. In trying to understand what art is and what artists do, I find ample support for the ideas that God in creating acts like an artist and that scientists in doing science are studying and interpreting God's art work and even creating art work of their own.

Central to Wolterstorff's theory is the notion that art is not created solely for the purpose of perceptual contemplation but rather is used purposefully by both the artist and the public. Art is an instrument for action (such as conveying an idea or providing aesthetic delight) and an object of action (such as contemplation or using a beautiful clay pot as a planter for flowers). Art in action is how "we carry out our intentions with respect to the world, our fellows, ourselves, and our gods" (1980a, 3). The artist may have a definite purpose for the public use of the art, but that does not prevent unintended uses and consequences.

Philosophers generally make common distinctions regarding the various types of art, and it is useful to have some definitions in hand. For Wolterstorff, art in its most general sense is "a skill, a craft, a competence at making" (1980a, 37), so ceramics, pottery, architecture, metal working, and some aspects of doing science all are arts, but they are not typically distinguished as *fine arts*. Fine arts, according to Wolterstorff, are those whose products "are regularly produced . . . or distributed with disinterested contemplation as one of the primary intended public uses" (p. 37), where disinterested contemplation is, as in Kant, contemplation undertaken for its own sake. A *work of art* for Wolterstorff is a product of one of the fine arts, so a knitted sweater technically would not be classified as a work of art although it is a result of art. I refer to such artifacts as *art work* to distinguish them from a *work of art*.

Wolterstorff acknowledges that "dense thickets of controversy surround the question of how 'work of art' is properly to be defined" (p. 17). In

leaving aesthetics out of the definition of a work of art Wolterstorff agrees with the influential philosopher and art critic Arthur Danto's definition of a work of art in that it has to be "about something" and has to "embody its meaning" (1997, 195).[3] Next, *high art* distinguishes those works of the fine arts that are produced for disinterested contemplation by the cultural elite of society. This would include art displayed in galleries, symphonies played by orchestras, and plays performed on stage. Wolterstorff rounds out the characterization of works of art with *popular art* and *art of the tribe*, both of which are, like high art, products of the fine arts. Popular art (romance novels or teen pop music, for example) is produced for the mass audience rather than the cultural elite, and works of the tribe (such as religious hymns, jazz, and commercials) are produced for all members of society. Tribal and popular art usually do not have disinterested contemplation as their chief purpose; the instrumental action of the art typically is entertainment or advertisement (interested contemplation).

Science and Nature as Art. Can the theories, mathematical proofs, and experiments of science be viewed as works of art? If so, are they fine art? The noted philosopher of science Norman Robert Campbell (1957) wrote passionately about the scientist's role as an artist. Science definitely can be construed as art because a scientist creates an artifact (a specific theory or experiment) using skill and craft. The medium of the work could be mathematics and/or existing scientific concepts, and it also could include the art of experimentation and instrument design.[4] According to Wolterstorff, science can be a fine art only if it typically is undertaken with the primary intent of disinterested contemplation. An experiment cannot be fine art because its primary purpose is to collect data. The purpose of forming a scientific theory, however, is to convey the scientific understanding of some phenomenon of the physical world. Although one could argue that a purpose of understanding the world for the scientific art work is consistent with disinterested intellectual contemplation, Wolterstorff mentions that philosophy would not count as a fine art because contemplation for its own sake is not the main purpose: "Philosophy is for increased insight" (1980a, 37). Likewise, science generally is for increased insight, not disinterested contemplation.

In addition to producing art work, scientists can be thought of as art critics and archaeologists. Art critics critique works of art and help the public better understand them. They write essays and columns that are also art work (not works of art, because their primary purpose is to inform and teach). Scientists are critics for nature, God's art work. Through technical papers and popular works (the scientists' art work) they educate the public to help them better understand creation. As observers and investigators, scientists also discover new aspects of creation's beauty, functioning somewhat like archaeologists as they dig for hidden treasures.

Although providing aesthetic delight often is a purpose for creating art, Wolterstorff claims that works of art usually are intended by the artist to be instruments of the action of "world projection," which is a theory of *mimesis* in representational art (1980b, xv). The world that is being projected is the world of the work of art, the state of affairs that is represented as given in that art work. What is the world of the work of art for God's art work, creation? Because humanity is part of that art work, the projected world is just the universe as we know it. However, if God can be taken to be engaging in mimesis, also, God's art work is shot through with the splendor of the heavenly kingdom; this composed world is in some way a representation of the ultimate real world of the Artist. World projection allows God to communicate with creatures through nature, to demonstrate that God exists and is a God of power, majesty, and beauty. This is general revelation, God's self-revelation through God's art work.

The last thing to consider here is the phenomenon of aesthetic delight. How does one make theological sense of this slippery concept that plays such a large part in nearly everyone's life? According to Wolterstorff,

> Aesthetic delight is a component within and a species of that joy which belongs to the shalom God has ordained as the goal of human existence, and which here already, in this broken and fallen world of ours, is to be sought and experienced . . . it becomes a matter of responsible action to help make available, to ourselves and others, the experience of aesthetic delight. (1980a, 169)

Aesthetic delight is a gift from God, a foretaste of the perfect shalom of heaven. Science provides a unique opportunity to taste that heavenly bliss. This quotation expresses a cultural responsibility for science, as well: to bring the joy of God's shalom to others by teaching the workings and interdependencies of the created order and revealing the unique aesthetic delights that are known only to those who are familiar with science.

Beauty and Methodology in Science. The phenomenon of beauty in science provides much more than aesthetic delight. Most philosophical work on the topic is devoted to the role beauty plays in actually guiding scientific work and discovery. In this section I describe and analyze the link between the beauty of God's art work and scientific methodology.

That secular and religious scientists alike attest to the role of beauty in science is fascinating, especially given the widely acknowledged demise of beauty in the modern and postmodern era. Hart writes that "in the climate of postmodern thought, whose humors are congenial to the sublime but generally corrosive of the beautiful, beauty's estate has diminished to one of mere negation, a spasm of illusory calm in the midst of being's sublimity" (2003, 15). Danto in his book *The Abuse of Beauty* claims that beauty has gotten a bum rap since Kant. Danto notes that "beauty rarely came up in art periodicals from the 1960s on without a deconstructionist snicker . . . there is the widespread sense that in some way beauty trivializes that which possesses it" (2003, 25–27).

Ironically, however, while Classical notions of beauty have been abused in other spheres of human art and creativity, modern science has flourished with the Classical conception of beauty that derives from the proper structure of the object—its organic unity, its size, symmetry, and definiteness (Beardsley 1966, 54). As traditional representational beauty in art evolved under the influences of German Idealism into the sublime aesthetic notions of Cubism, Dadaism, Abstract Expressionism, and Conceptualism during the majority of the twentieth century, science has largely stuck to its Classical aesthetic criteria while steadily revolutionizing the world. Physicist Werner Heisenberg described beauty in science as being that of the ancients, "the proper conformity of parts to one another and to the whole" (1974, 169). Gideon Engler (1990) lists the aesthetic concepts of science as being symmetry, simplicity, order, coherence, unity, elegance, and harmony. James McAllister's list has some items unique to science but retains many Classical concerns (1996, 40).[5]

As McAllister analyzes in great detail, beauty often is used as a methodological tool in scientific research. Aesthetic pleasure is not just a concomitant by-product of finding the correct solution; seeking out aesthetic pleasure often is an important means of finding that correct solution. McAllister in holding to a rationalist explanation of science argues that the "aesthetic canon" used by a scientific community is used inductively to help arrive at correct solutions. However, he denies that the successful use of aesthetics in science proves a necessary or fundamental link between beauty and truth (1996, 100–102). Many scientists would disagree.

John Polkinghorne, who has written extensively on the relationship of science to Christian theology, invokes the presence of beauty in the world and in science to argue against scientific reductionism. He emphasizes the irreducibility of human experience by referring to its richly structured, many-leveled nature:

> I take utterly seriously our experiences of beauty. I think they tell us something about reality. Beauty is not just a sort of froth on the surface of things. It is something very deep about the world. So how am I to understand the remarkable fact that the physical world is also the carrier of beauty? That is what I mean by many-leveled structure; there is beauty in the world as well as physics. (1995, 8)

Scientists rationally pursue the order of creation, but that rationalism is not a cold and sterile quality permeating the scientific enterprise or the physical world because the beauty infused by God into creation can never be reductively separated out and dismissed.

Paul Dirac commented on his search in the 1920s for a connection between quantum mechanics and relativity theory:

> It is more important to have beauty in one's equations than to have them fit experiment . . . because the discrepancy may be due to minor features which are not properly taken into account and which will get cleared up with further developments of the theory. . . . It seems that if one is working from the point of view of instinct, one is on a sure line of success. (1963, 47)

Kitty Ferguson responds: "Beauty is a subjective thing—'in the eye of the beholder,' we are told—what could be more subjective than that? But beauty is a familiar pointer in physics" (1994, 60).

This is the fascinating thing: A supposedly subjective aesthetic judgment is shown over and over to be a signpost to universally held scientific truths. This is not quite parallel to Kant's dilemma in the *Critique of Judgment* (1987) where he attempts to explain why subjective judgments of beauty are held as if they should be universal. In the case of science, what is found to be universally valid is the scientific truth the beauty points toward rather than the judgment of beauty itself. A Christian has little trouble explaining this in general terms, although it does not diminish the wonder of it: God created the world with a good, beautiful order; we are part of that world and created in God's image; and we therefore have an instinctual desire to seek that beautiful and rational order. If God is an artist and the universe is God's beautiful art work, it is not surprising that the blueprints for the universe also are beautiful.

Part 2: Scientific Aesthetics

The Sublime. The sublime is not usually referred to explicitly by scientists, but it is for all practical purposes synonymous with the awe and wonder that are mentioned.[6] Neither awe nor wonder necessarily connotes the sense of fear described by Edmund Burke, but, as Danto points out, "There may be cases where the experience of the sublime has terror as a component feeling, but it is not integral to the concept, in the way wonder itself is" (2003, 155). Scientists use other words also to express experiences that must involve the aesthetic sublime. Weinberg gives a good sampling of these words while discussing the role of beauty in theory formulation: *spooky*, *weird*, *amazing*, and *strange* (1992, 133–57).

In modern and postmodern accounts, to experience the sublime is to experience the collapse of representation, when something of the nonrepresentable is somehow presented to the subject. The sublime is the downfall of mimesis, the representative role of art and language that seeks to symbolize and communicate something of an objective reality. It thus stands in contrast to beauty (but, as we shall see, is not necessarily separated from beauty). Beauty is formed and finite and phenomenally represented, presented as a sensible object to our cognitive faculties—even in the case of purely cognitive scientific theories, the beauty of which is presented to us through their representations. The sublime is associated with the feelings accompanying contemplation of the infinite, the unformed, and the unrepresentable aspects of either reality or our own rational activities. These feelings traditionally are not feelings of pleasure, the type of feelings associated with contemplation of the beautiful or good. Rather, they are feelings of pure boundless freedom, but not a freedom associated with goodness

or virtue. According to Kant, the pure freedom is what makes possible humanity's superiority over nature—the condition that allows us to act of our own free will and respond to duty.

It is difficult to overestimate the cumulative impact of Kantian and post-Kantian notions of the sublime on philosophy, theology, and art. Hart offers one definition of postmodernism as "narratives of the sublime" and states: "Sublimity is critical fashion, here on the far side of modernity; and it is—with whatever degree of conceptual alteration—the sublime of Kant's *Critique of Judgment* that has come to define the nature of this fashion" (2003, 44). Wendy Steiner offers a feminist critique of the sublime in her book *Venus in Exile* and comments on the ascendancy of the sublime:

> . . . in the course of the contrast between the beautiful and the sublime, the beautiful and the charming fall together, both are connected to the female and to love, and the sublime ends up the only uncompromised experience of beauty. Though Kant stated overtly that the beautiful was as legitimate an experience of beauty as the sublime, modernists responded to the metaphoric undertones of his words. The ideology of the avant-garde was based on the uncompromising, "masculine" distance of the sublime. (2001, 16)

The sublime is hardly a new topic, having undergone a steady critical development in aesthetic theory beginning with the British empiricists in the seventeenth century, flowering with Burke's *Philosophical Enquiry into the Origin of Our Ideas of the Sublime and the Beautiful* (1757), and continuing on through modern German philosophy with Kant, G. W. F. Hegel, the Romantics, and Friedrich Nietzsche. The philosopher Shaftesbury, writing in the later seventeenth century, was among the first to elevate nature as an object of aesthetic contemplation comparable to art (Beardsley 1966, 182). He thought of nature as being produced by God, the greatest of all artists. Contemplating nature as God's art work meant that ordinarily wild and fearsome things such as rugged cliffs, raging seas, vast deserts, and the vastness of the cosmos were seen with a new sort of pleasure. These aspects of nature are still not beautiful, per se, but they evoke a feeling of the sublime within us, a feeling of aesthetic pleasure resulting from the size of such objects in relation to our mind. For people of faith it can be a religious experience, which is equated with attributing the particular experience of the sublime to an experience of God.

As with beauty, scientists typically disregard modern aesthetic tendencies and express a more Classical, pre-Kantian understanding of the sublime in line with Shaftesbury and the other British empiricists. This notion is echoed in what is perhaps the only extensive work on the sublime in science, Celia Deane-Drummond's recent book *Wonder and Wisdom*. "The natural world," she writes, "gives us a direct experience of wonder. Such experiences can, in some cases, lead to a sense of the transcendent and experience of religious awe rather like that portrayed through landscape painting and abstract art" (2006, 133). The sublime experience, for Deane-

Drummond as for Einstein, leads to God. Einstein, a self-avowed deist, expresses this openness to a transcendent sublime in his essay "What I Believe":

> The most beautiful emotion we can experience is the mysterious. It is the fundamental emotion that stands at the cradle of all true art and science. He to whom this emotion is a stranger, who can no longer wonder and stand rapt in awe, is as good as dead, a snuffed-out candle. To sense that behind anything that can be experienced there is something that our minds cannot grasp, whose beauty and sublimity reaches us only indirectly: this is religiousness. In this sense, and in this sense only, I am a devoutly religious man. (1930, 194)

Judgments of Beauty in Science. One thesis of this article is that in science an experience of the sublime often follows on the heels of a judgment of beauty. Before examining specific examples of the sublime in science, therefore, I take a closer look at beauty in science. In Part 1 I discussed beauty in more general terms as it relates to methodology, but here the focus is on Kant's aesthetic theory and specific scientific examples involving beauty.

It is quite commonplace for the fruits of science to be deemed beautiful, including both the new natural phenomena that are uncovered and the new theories that are formulated. Examples of this type of beauty range from a newly discovered beetle to Erwin Schrödinger's wave equation for quantum mechanics. Often a theory is just happened upon and deemed beautiful only when it has been established as being empirically correct (McAllister 1996, 66).

Because much of God's creation and science have other purposes besides the aesthetic pleasuring of humanity, judgments of beauty regarding these things, even if made while abstracting the object's purpose, would be characterized by Kant as *accessory* beauty (1987, sec. 16) and could not be claimed as a universally necessary judgment of taste—that is, one could not expect everyone to make a similar judgment. When we desire an object for our own gratification or simply for its goodness (that is, we find it agreeable) and cannot ignore or abstract this liking, we cannot make an aesthetic judgment (of beauty or sublimity). Such objects are said to have charm or allure rather than beauty. In aesthetic judgments of scientific theories or creation, it seems that accessory beauty is more commonplace. For instance, one can ignore the purpose behind Heisenberg's formulation of quantum mechanics (to more fully describe the physical universe) and still judge the theory to be beautiful. There does seem to be nearly universal agreement over the accessory beauty of many scientific theories, but it would be difficult to argue that these involve *necessary* judgments of beauty. As McAllister notes, universal agreement is likely related to the fact that the theory works (1996, 102).

There are many examples in nature and science, though, where pure judgments of beauty are possible. New creatures found at the bottom of

the ocean, synthetic star-shaped dendritic polymers, and the Grand Tetons have no clear purpose that would potentially pollute a pure aesthetic judgment. The matter of a sunset is a different story. If it is to be viewed as God's art, we clearly know the purpose of the sun and its setting (lets us sleep, marks time). Although we can abstract those purposes out in judging a stunning sunset to be beautiful, Kant would not allow for an expectation of universality of that judgment as it would be merely accessory beauty. This seems empirically falsifiable given the archetypal status of beautiful sunsets (though Oscar Wilde does provide an exception,[7] and perhaps it is culturally conditioned).

Kant does not dwell long on the concept of accessory beauty, and he also does not allow a link between the beautiful and the sublime. A sunset in his scheme could not be both beautiful and sublime. These shortcomings indicate that Kant's aesthetics are not exactly what is needed to help us understand the beauty found in God's creation and scientific activity. Scientists do not always ignore their interest in the objects they judge beautiful, yet they seem to generally agree on what is beautiful. These beautiful objects and concepts related to them are often deemed sublime, as well, partly due to our interest in them. Kantian aesthetics have been critiqued in fields other than theological aesthetics; for example, Steiner (2001) traces the deleterious effects of Kantian aesthetics on women over the last two hundred years and highlights Mary Shelley's foreboding vision of these aesthetics in *Frankenstein*.

With a backdrop of aesthetic theory now in place, let us explore a specific example of sublime beauty in science. Richard Smalley, together with Harold Kroto and Robert Curl, received the 1996 Nobel Prize in Chemistry for discovering C_{60} (buckminsterfullerene, or "bucky balls" as they are affectionately known). C_{60} is a new allotrope of carbon in which sixty carbon atoms bond together to form a molecule that looks exactly like a soccer ball, with single carbon atoms making the vertices of the five- and six-sided panels that make up the surface of a soccer ball. Shortly thereafter a similarly shaped C_{70} appeared along with many other types of this new class of molecules now known simply as fullerenes. Included in this class are the famous carbon nanotubes, which can be thought of as graphite rolled into a narrow tube. All of these are undeniably beautiful, owing to their symmetry and unique shape. As Kroto remarked in his Nobel lecture, "The story of C_{60} cannot be recounted without reference to its beauty which results from the incredible symmetry." Smalley in his own Nobel lecture (2003) stated: "This discovery was one of the most spiritual experiences that any of us in the original team of five [has] ever experienced. The main message of my talk today is that this spiritual experience, this discovery of what Nature has in store for us with carbon, is still ongoing." The experience was sublime for Smalley and thousands of other scientists who heard about the discovery because with everything that science had already

produced no one would have dreamed that such a form of carbon existed. It is akin to, say, Mozart's meeting Miles Davis and hearing jazz music for the first time. He would hear the same familiar musical notes, but used in a wholly other way that scarcely resembled the structures and uses for notes that he knew so well.

Smalley in his speech (2003) reiterated that they were not being awarded the prize for dreaming up the unique structure and stability of C_{60}; that was done rather obscurely by Eiji Osawa in the early 1970s, and others had speculated on its physical properties should it exist. He continued:

> Instead, the discovery that garnered the Nobel Prize was the realization that carbon makes the truncated icosahedral molecule [C_{60}], and larger geodesic cages, all by itself. Carbon has wired within it, as part of its birthright ever since the beginning of this universe, the genius for spontaneously assembling into fullerenes . . . these objects of such wonderful symmetry.

Clearly buckminsterfullerene is beautiful, but Smalley's description is of an aesthetic experience that moves beyond a judgment of pure beauty, it seems, for he is positing a wiring of carbon atoms by genius. This requires further elucidation.

The Sublime in Science. That carbon reflects genius may simply have been an analogy used by Smalley, but his invocation of the spiritual as well indicates that he may not have known how to adequately describe his response to carbon's sublime behavior. He hints at transcendent experiences brought on by the sublime discovery of the buckminsterfullerene molecule. Scientists, both religious and secular, have long acknowledged the sublime or something like it that occurs when they contemplate some particularly incredible instance of scientific insight or beauty, particularly when it has far-reaching consequences for life or the cosmos. This aesthetic experience is not, as Kant believed, strictly limited to sensations of immense magnitude or force.

Another example of the sublime in science is the intricate mechanism of photosynthesis. For one thing, the time scales of reactions that initially convert absorbed sunlight into electrical potential energy are in the nanosecond (one billionth of a second) to picosecond (one trillionth of a second) range. These time scales and the precise arrangement of the many molecules involved are critical for proper functioning of the process. A reaction that occurs in ten picoseconds is too fast for us to comprehend fully. Consider that the duration of ten picoseconds compared to one second is the same as one second compared to more than 300,000 years. We can put a number on it and measure it, but we cannot fathom it. Contemplating photosynthesis is thus a sublime experience on many different fronts. The process is beautiful and works so well that it seems to be designed. Even less complicated single proteins are regularly referred to as *molecular machines* by scientists. That this complex process points to a grand designer

is a sublime thought, and the notion that the process works *as if* it had been designed also is sublime. That mindless plants can take air and water and convert them to sugar is beautiful and sublime. Notice that extra concepts are brought in to make the experience of the object sublime, and the same object is deemed to be beautiful and sublime. These are also clearly interested rather than disinterested aesthetic judgments.

For the theist, this sublime experience is naturally transferred to an experience of the transcendent, for the viewer is given an intimation of the power, omniscience, and creativity of God, or at the very least a glimpse of the power and creativity of evolution, which can be taken to be a tool of God. It is an aesthetic experience that would have been impossible a hundred years ago because it was not known how photosynthesis worked. For the theist, scientific discovery and science education made this new insight into God's majesty possible.

A more generic example of the beautiful and the sublime is taken from materials science. An image of the surface of a clean piece of copper taken with atomic-level resolution by an atomic-force microscope shows a regular crystalline pattern of copper atoms. Without regard to any other concept concerning the image or the copper, one would say that the perfect pattern of the atoms, with none out of place, is beautiful. The *form* of the image is aesthetically pleasing. Additionally, the scheme of the experiment can be judged to be beautiful. The clever manner in which the laser beam is reflected off a minute stylus and the precise machining of the near-atomic-level size of the scanning tip are aesthetically pleasing, even without regard to their purpose.

However, these same things when joined with other concepts, such as the scale of the image or the stunning smallness of the manufactured tip, also lead to an aesthetically sublime experience. It is mind-boggling just how small the tip is, and it is nearly unfathomable how such macroscopic pieces of metal can generate an accurate image of things a billion times smaller than themselves. It is also sublime to consider that the copper atoms that are imaged so clearly are overwhelmingly nothing but empty space. The repulsion of the tip is a function of the electron cloud of the atom, but the space occupied by virtually all the mass of the atom, the nucleus, is minuscule, only about *one millionth of a billionth* of the volume of the atom. The rest is empty space filled with electron waves. We are just like that, constituted by atoms that are mostly nothing.

These thoughts are sublime in that they lead to an agitated or befuddled state. We are unable to cope with the inability of our imagination to present these concepts to our rational faculties. We are nonetheless pleased that we know these things to be the case, even if we cannot fully grasp it; we feel blessed to be privy to this knowledge. The focus of sublime aesthetic contemplation is no longer on the form of the presented object. This is basically the pattern of sublime experience outlined by Kant, but there is a

twofold deviation: The sublime experience is linked to a judgment of beauty, and other concepts of interest are associated with the sensed object, none of which leaves our mind during the experience—there does not seem to be the purely internal focus on our mental capacities.

Specific scientific discoveries or theories thus bring about sublime feelings, but so also do general themes in science. One of these is that the universe is amenable to mathematical and scientific understanding. Wigner, the physics Nobel laureate of 1963, published a short paper on this theme, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." He concludes:

> The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend, for better or for worse, to our pleasure, even though perhaps also to our bafflement, to wide branches of learning. (1960, 14)

For the theist, this strange effectiveness of mathematics is a matter that leads to worship of the transcendent Artist.

Although not all scientists associate a sublime experience with a transcendent religious experience, they typically do not associate it with the Nothingness or Abyss of postmodernists. They attach great meaning to the experience and, like Einstein, use it as a source of motivation. Astrophysicist S. Chandrasekhar commented on the most "shattering" experience in his entire career when he grasped the consequences of a particular solution of Einstein's equations of general relativity: "This 'shuddering before the beautiful,' this incredible fact that a discovery motivated by a search after the beautiful in mathematics should find its exact replica in Nature, persuades me to say that beauty is that to which the human mind responds at its deepest and most profound" (1987, 54).

A notable and instructive exception in his resistance to the allure of the sublime in science is Weinberg, who denies belief in any sort of personal or caring God. He comments on the sublime that "there are some among my scientific colleagues who say that the contemplation of nature gives them all the spiritual satisfaction that others have traditionally found in a belief in an interested God. Some of them may even really feel that way. I do not" (1992, 256). On observing the beauty of the trees and birds outside his window, further contemplation leads him to what must have been a sublime experience: "Although I understand pretty well how brightly colored feathers evolved out of a competition for mates, it is almost irresistible to imagine that all this beauty was somehow laid on for our benefit. But the God of birds and trees would have to be also the God of birth defects and cancer" (1992, 250). The sublime experience was "almost" an irresistible experience of transcendence. He offers an even more telling rejection of the sublime when commenting on the well-known psalm of

David, "The heavens declare the glory of God, and the sky above proclaims his handiwork" (Psalm 19:1 ESV). Says Weinberg,

> Since David's day the sun and other stars have lost their special status; we understand that they are spheres of glowing gas, held together by gravitation, and supported against collapse by pressure that is maintained by the heat rising up from thermonuclear reactions in the stars' cores. The stars tell us nothing more or less about the glory of God than do the stones on the ground around us. (1992, 241)

Weinberg in general is not resisting the sublime experience, just the notion that it indicates any sort of transcendence.[8]

On Transcendence and the Relationship between Beauty and the Sublime. One might describe the sublime moment as a religious experience, for it intimates a universal transcendence that can be taken to be divine. The agnostic scientist and the theist alike testify to the sublime, and the sublime along with the beautiful motivates them both and even guides them to discover scientific truth. The basic question to be answered is why humans experience sublime moments when contemplating nature or scientific theories or even some works of art. Why do humans universally report a type of aesthetic experience that goes beyond what is normally described as an experience of beauty, a phenomenon that is like beauty but different? It is not good enough to merely acknowledge the phenomenon, or even to gush about it as many scientists are wont to do, without attempting to understand it from a philosophical and theological perspective.

According to Kant, the traditional sense of beauty is completely separate from the sublime in that beauty is tied to the form of the object whereas the sublime is in the end divorced from the object and results from a pure self-analysis and revelry of the mind:

> . . . in what we call sublime in nature there is such an utter lack of anything leading to particular objective principles and to forms of nature conforming to them, that it is rather in its chaos that nature most arouses our ideas of the sublime, or in its wildest and most ruthless disarray and devastation, provided it displays magnitude and might . . . this [sublime] concept indicates nothing purposive whatever in nature itself but only in what *use* we can make of our intuitions of nature so that we can feel a purposiveness within ourselves entirely independent of nature. (1987, sec. 23)

I argue that the Kantian and modernist formulations of the sublime (and beautiful) are inadequate to explain the aesthetic experiences encountered in science. The uniqueness of sublime experiences in the sciences is that they are inextricably linked to the concepts and purposes of the original object, whether it is a physical object or a scientific explanation. The sublimity of non-scientifically appraised natural objects such as the Alps, however, is perhaps more amenable to a Kantian account because additional scientific truths are not necessary for the experience; it is not necessary to consider the massive geological forces that birthed the Alps in order to sublimely experience them—although geological theories on mountain

formation may occasion a separate experience of the sublime. It is important, therefore, to look more closely at recent critiques of Kantian and modernist aesthetics and to examine alternatives to an explanation of the sublime and the beautiful.

Milbank, in a piece titled "Sublimity: The Modern Transcendent" (1998), argues that postmodernists have arbitrarily substituted a purely subjective sublime experience for transcendence. Where some argue that sublime experiences such as those that come from pondering scientific truths lead to objective knowledge of transcendent truths about reality and intimate a transcendent God, postmodernists following in the subjective line of thinking since Kant have preferred to think that the sublime leads to nothing objective but rather to a completely subjective opening into the abyss.

Milbank notes another characteristic of the sublime, however, and that is the notion that God is the "paradigmatic instance of the sublime" (1998, 259). Because premoderns did not rigorously distinguish experience of the sublime from the beautiful, the sublime, transcendent qualities of God were wrapped into his beauty; the unlimited and unrepresentable was viewed as an "unimaginable fullness of the beautiful form, not its negation" (p. 260). Modernists and postmodernists, however, in separating sublimity from beauty also have substituted transcendence for sublimity, leaving no vestiges of the beautiful or conceptual attributes originally associated with the pre-Kantian and pre-Burkean sublime. So, all that remains of the transcendent experiences or absolute postulates is "sheer unknowability or its quality of non-representability and non-depictablility" (p. 259). Milbank argues that this is an arbitrary gesture that does not necessarily follow from any of the various postmodern projects.

Milbank disagrees with Kant that judgments of beauty must be disinterested. In fact, often they are accompanied by a special interest. The desire accompanying a judgment of beauty is a desire for something more, something beyond beauty, something that has not been represented but is still desired due to a representation. This desire is actually an instance of the sublime:

> In denying that there exists any such extra-erotic, disinterested beauty, one can *also* see that there is no sublime terminus except that which is opened up by a beautiful approach. What mountain is sublime merely because of its size? Surely its grandeur is rather a matter of the way its specific form suggests the uniquely overwhelming, and the way it both is and is not in continuity with a harmonious, beautiful approach towards it, or the *picturesqueness* of a vista. . . . It is true that certain experiences are relatively more beautiful and others relatively more sublime, yet neither can be entirely the one without something of the other. (pp. 268–69)

Hart goes even further and argues that the sublime experience is actually just another experience of the beautiful: ". . . there is no aboriginal sublime that surpasses the moment of the beautiful; rather, the sublime

appears as a particularly intense serial display of beauty, a particularly weighty manifestation of God's glory" (2003, 277).

These accounts of beauty and the sublime are surely more in line with what occurs in the natural sciences.

Kant never ventured to say that the beautiful could lead to knowledge of the object, for it was purely a subjective feeling brought on by perception of the object. Aesthetic judgments of beauty were strange in that they were subjectively felt to be universalizable even though they were not grounded in conceptual reason. This intersubjectivity of beauty meant that there could be public agreement that was not conceptually grounded. Milbank sees a coupling of this aesthetic feeling with both practical and theoretical reason that could have led Kant to an antifoundationalist epistemology that "operates only on the ground of intersubjective acceptance of judgment of harmony without reasons other that those of its own subjective occurrence" (1998, 274).

Is this not exactly what science ultimately is? The Gödel incompleteness theorem and the Kuhnian critiques of the scientific enterprise have forever washed away any absolute rational foundations in the natural sciences. Maxwell's equations of electromagnetic radiation are surely correct, and one can be convinced of that based on a mathematical proof and an observation of how the theory meshes with the data. The equations are not an example of a foundational science, however, because ultimately they are not the end of our understanding of light. There is no mention of the photon (the quantum unit of light), much less quantum electrodynamics. Milbank is arguing for an epistemology that incorporates aesthetics with reason. The scientific enterprise already manifests such an epistemology. Scientific papers and theories are not accepted entirely on the basis of deduction and proof. An aesthetic intersubjective acceptance based on harmony with existing scientific understanding also plays a role, and beauty is a reliable guide for reason in the search for new scientific truths.

In the end, we must ask if the intense aesthetic pleasures a scientist experiences in doing science are purely subjective responses, or if there is always an element of the transcendent involved, a bridging of the phenomenal-noumenal gap that is like an act of grace mediated by something other than the object. The theist sees a transcendent God here rather than a mere sublime experience of an unknowable, unrepresentable abyss. Jerome Miller argues that experiences of the sublime are intimations of a transcendent God, where the sublime is an experience of true being and otherness. "The experience of awe [in a sublime moment] involves our feeling overwhelmed by a reality wholly Other . . . the transcendent Other which we do not find outside our experience of awe but only within its throe." However, Miller continues, "Awe itself can do no more than expose us to the possibility of this transcendent Other; it is up to us to judge whether there are good reasons for affirming the reality of it" (1992, 190–91).

NOTES

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1. For a discussion of evolutionary aesthetics see Pinker 1999.
2. The citations for the other references in this paragraph are as follows: Aquinas (*Summa Theologica*, I, q. 44, a. 3; I, q. 65, a. 3; I, q. 73, a. 3), Bonaventure (*The Soul's Journey into God*, 1.3, 2.9), Augustine (*Enchiridion*, 23.89), and Basil (*Hexaemeron* 3, sec. 10).
3. An important distinction between Danto and Wolterstorff, however, is the latter's definition of a work of art requiring that it be a product of one of the fine arts. Danto would include anything presented for disinterested contemplation as a work of art, which admits the ready-mades of Marcel Duchamp and other modern art that Wolterstorff prefers to put in a different category.
4. The mediums used for scientific theory formation obviously are more akin to the mediums of words and ideas used in poetry and literature than to the physical mediums used in painting and sculpture.
5. Peter Kivy (1991) has argued that only Classical notions of beauty show up in modern science because science can be viewed as a form of realistic representational art, where a goal of the art work is to represent nature or the external world as accurately as possible.
6. Jerome Miller has a helpful discussion on different meanings associated with awe and wonder (1992, 188).
7. The thoroughly modern Wilde famously wrote that "Nobody of any real culture, for instance, even talks nowadays about the beauty of a sunset. Sunsets are quite old-fashioned . . . to admire them is a distinct sign of provincialism of temperament" ([1889] 1965, 22).
8. Noted scientist and skeptic Richard Dawkins (1998, 17) makes a similar comment regarding the sublime.

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