"He" Had Me at Blue: Color Theory and Visual Art

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ABSTRACT

Schopenhauer and Goethe argued that colors are dangerous: When philosophers speak of colors, they often begin to rant and rave. This essay addresses the confusing and treacherous history of color theory and perception. An overview of philosophers and scientists associated with developing theories leads into a discussion of contemporary perspectives: Taussig's notion of a "combustible mixture" and "total bodily activity" and Massumi's idea of an "ingressive activity" are used as turning points in a discussion of Roger Hiorns's *Seizure*—an excruciatingly intoxicating installation.

Blue is the colour of your yellow hair
Red is the whirl of your green wheels

—Kurt Schwitters

Color Mad

A friend and colleague once confided that she hated yellow flowers: "I can't," she blustered, "have them in my garden."

"You sound like a scene from a Hitchcock movie!" I teased, and Tippi Hedren as Marnie flashed before my eyes.

> Marnie: "First there are three taps."
> Thunder claps. Marnie swoons, wailing: "Needles . . . Pins . . . Black! . . . White! . . . Red! . . . White! . . . White!"
> *Red light* floods across the white draperies and walls.
> "The colors," Marnie shrieks and recoils. Collapsing onto the floor she pleads, "Stop the Colors!" [1].

To visualize the main character's breakdown in *Marnie*, Hitchcock draws on Western attitudes toward the color red. Historically, red is the color imaginatively associated with heat and passion. Its conceptual relationship to emotional or physical calefaction comes as no surprise: Scientifically, red is closest to the infrared part of the electromagnetic spectrum, in which thermal waves reside. Indeed, Johann Wolfgang von Goethe, a 19th-century Romantic playwright, poet and naturalist, was one of the first scholars to delve into such cross-disciplinary aspects of color. In *Theory of Colours,* published in 1810, Goethe connects subjective and objective apprehensions: "In some states of body," Goethe contends in his appendix on pathological colors, "when the blood is heated, and the system much excited," fiery flashes of red light may appear [2].

The flashes of light trigger Marnie's psychological disintegration, and her psychological trauma manifests as an "overheated" body. We readily accept her colorful projection because our visual perception system lends itself to such subjective episodes. As Goethe further observed, exposure to intense light has the potential to produce "dazzling" and overwhelming effects. It can leave an intolerable and "powerful impression" and result in a type of visual incapacitation that, he suggests, "may last for hours" [3]. Exposure to blazing light—"red" or "white" light, as the fictional character cries—in real life can result in blinding aftereffects; for example, walking out of a dark corridor into a bright, sunlit room. Occurrences of such illusions or optical "whiteouts," which are momentary and do not last as long as Goethe suggests, make Marnie's hallucinatory condition palpable, and her delusory state resonates with our perceptional systems.

Whether aesthetics or taste, illusion or hallucination, our responses to color run a gamut. Color perception, however, can also elicit intense sensory responses. For instance, I recently stumbled across documentation of Roger Hiorns's installation *Seizure* (2009–2010) (Article Frontispiece). To produce the artwork, the British artist pumped copper sulfate solution into an abandoned council flat, and ultramarine-blue crystals grew on the walls, floor and ceiling. The resultant crystalline crust, very visible in the photographic documentation, is excruciatingly intoxicating. The intensity of the blue gives rise to what Henri Matisse called the "vivacity" of color, or intense "retinal sensation." Color, as the early avant-garde artist suggested, produces a physiological liveliness that potentially can jump across the senses and invoke tactility or cause palpitations. He compares such trembling to the "'vibrato' of the violin" [4].

In "Too-Blue: Color-Patch for an Expanded Empiricism," Brian Massumi argues that color in general, and blue in particular, has such dynamic potential; like Matisse, Massumi uses the term "vivacity." Going beyond synesthesia or cross-sensory responses, Massumi argues that color perception is a "*self-activity* of experience," an "ingressive activity" [5]. He ultimately aligns it with what 19th-century psychologist William James called *pure experience*—"the immediate flux of life which furnishes the material to our later reflection with its conceptual categories." Pure experience is, he states, "a *that* which is not yet any definite *what,* tho' ready to be all sorts of whats; full both of oneness and of manyness, but in respects that don't appear" [6].

This essay addresses the confusing topic of color perception: what Arthur Schopenhauer, writing almost two centuries ago, described as a "perplexing" and "dangerous" topic for philosophers and scientists [7]. Quoting Goethe, Schopenhauer further warned that if the philosopher speaks of "colour only in a

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Article Frontispiece. Roger Hiorns, *Seizure*, installation, 2008. Opened in 2008, in a condemned Southwark, London, flat, the installation was closed to the public in January 2010. While the housing block was demolished in 2011, Hiorns's work was preserved and acquired by the Arts Council Collection. The 31-ton piece was cut out and relocated to the Yorkshire Sculpture Park; according to their website, *Seizure* is currently open to the public—even over the Easter weekend. (© Roger Hiorns. Photo: Marcus Leith. Commissioned by Artangel and the Jerwood Charitable Foundation, supported by the National Lottery through Arts Council England, in association with Channel 4. Courtesy of the artist and Corvi-Mora, London.)

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general way," he or she—like a bull—*sees red*, and "begins to rave" [8]. Such raving continues to haunt the debate. As Martin Kemp states:

> If there is anything upon which almost all the writers on colour agree, from the time of Aristotle to the present day, it is that colour . . . presents a bewildering variety of kaleidoscopic variations—fleeting, fluctuating, and almost infinitely slippery whenever we try to entrap them in a regular net of scientific categories [9].

At the risk of perpetuating such heated or cooled madness, this article touches upon the combustible history of color vision. Following Evan Thompson, the approach is multidisciplinary, encompassing perspectives from neuroscience to cellular biology, psychophysics, linguistics, philosophy and artificial intelligence [10]. Yet, instead of "abstracting away," as Rainer Mausfeld warns [11], this essay clings to the vivacity of color perception. Its ultimate focus turns on the many-sided "whatness" that arises out of internal vibrations that resonate with external fluctuations. With that in mind, it reincorporates an often overlooked, albeit parallel and equally engaged inquiry—artistic investigation into the realm of color perception.

What Is Color?

Although Aristotle was one of the first to formulate a theory on color, he was more interested in the visible nature of color than the behavior of pigments. In *Sense and Sensibilia*, Aristotle argued that visible color resulted from mixing lightness and darkness; white and black represented the outer limits of the color spectrum and proportional mixing between them gave rise to the "plurality" of visible colors [12]. Although subsequent scholars, from Leon Battista Alberti to Leonardo da Vinci to René Descartes, proposed various ways to quantify the phenomenon of color, Isaac Newton modernized its study.

A key moment within the history of color theory, Kemp contends, was 1666: the year in which Newton used an optical prism to perform "his *experimentum crucis*," demonstrating that white light was a heterogeneous mixture of differently "refrangible" rays and splitting it into its "constituent elements" [13]. Instead of modifying light to produce colors, he proved that when light refracts through the prism, it separates or bends into a continuous range of refrangible rays [14]. As Newton proposed, the experience of color corresponds to different "degrees of refrangibility," through which individually refracted rays have a "disposition to exhibit this or that particular color" [15]. The color-producing rays are proportionally related, and, using the sequence found in naturally occurring phenomena such as rainbows, Newton keyed his prismatic spectrum to the ratio-related system of musical chords, producing a descending array of hues: red, orange, yellow, green, blue, indigo and violet. Newton, then, took his "linear diagram of spectral intervals" and "joined [it] at its distal ends" [16]. In doing so, he turned his color octave into a two-dimensional circle. While others, including Aristotle, had used a circle to demonstrate their theories, Newton's color wheel visualized the complementary and analogous relationship between hues.

Radically breaking from Aristotle's proportional mixtures of lightness and darkness, Newton published his proofs in *Opticks* (1704) and, as Georg Stahl proclaims, "set off a revolution in the studies of light and color" [17]. By 1800, Kemp adds, "Newtonian prismatics had . . . become part of the general currency of academic knowledge." Yet, throughout the 18th century, many hotly debated his findings—even scientists within the prestigious group of scholars associated with the British Royal Society, of which Newton had become president [18]. Louis Bertrand Castel, Anton Mengs and Sir David Brewster were a few of his latter-day detractors [19]. However, Goethe's attack is what led, rather than to a correction in Newton's theories, to a shift within the modern science and philosophy of color theory.

At some point in the early 19th century, Goethe hastily attempted to replicate Newton's spectral experiment. In his curtailed application, he saw not a full projection, but a thin prismatic stripe of colors, hovering at the edges, in the boundary between the light and dark areas on the wall [20]. Dismissively, he referred to Newton's prismatic division as a false hypothesis, and wrote *Theory of Colours* as a polemic. Goethe went so far as to visualize the British scientist's theoretical doctrine as a castle in ruins, beyond the possibility of renovation. Newton's ideas, he proclaimed, needed to be dismantled "from gable and roof downwards" so that sunlight "may at last shine into the old nest of rats and owls" [21]. After his searing critique, Goethe proposed his own theories of the "physiological," "physical" and "chemical" features of colors.

Schopenhauer became interested in Goethe's *Theory of Colours* around the time of Goethe's death, although the work was poorly received in the Romantic poet and naturalist's lifetime. Schopenhauer understood the importance of its physiological analysis of color perception and, even though he was critical, used Goethe's insight to stake out his own position:

> All color theories share the same mistake . . . they all speak only about what modifications light or the surface of a body must undergo to show color. . . . Instead, the correct way is obviously to direct our attention, first of all, to the sensation itself and to investigate if we could not determine from its nature and conformity what it consists of physiologically, in itself [22].

Building on Goethe's theory of the physiological effects of color, Schopenhauer directed "attention, first of all, to the sensation itself"—the physiological response produced in the eye [23]. The object of Newton's study, he asserted, "was light when it should have been the eye" [24].

The debate within color and perception theory today is far from a unanimous resolution. As Joseph Levine modestly puts it: "Our best theories of color vision, including the popular opponent-process theory, tell us that color experience is a very complicated process" [25]. "The central problem," he suggests, is that color "doesn't sit easily . . . out in the world or entirely within the mind" [26]. In short, the focus of the theory today has shifted from the *what* to the *where* of color.

Where Is Color?

To understand current perspectives, three interrelated aspects need definition. First, as Levine simply states, "*Yellow is out there*: you can see it" [27]. The yellow that is out there concerns not a differing degree of refrangible ray, as Newton had it, but, in our modern-day terminology, electromagnetic waves and photon particles. As Stephen Palmer explains: "Light consists of minute packets of energy called photons that behave like waves in some respects and like particles in others" [28]. Refracted rays are not, in themselves, colored; color only appears when visible light, comprised of various wavelengths, hits a surface. The struck surface absorbs the short (violet-blue) and the long (red-orange), but reflects the medium (green-yellow) lengths. Yellow photons then radiate from the tulip petals, dahlia centers and sunflower heads.

Second, yellow is not just out there as a function of absorbed and reflected electromagnetic radiation. It is constantly modified though ambient environmental conditions. As Levine explains, a large number of parameters determine color perception, such as "the kind and intensity of illumination" and "spectral reflectances of surrounding surfaces" [29]. Lighting conditions and other optical environmental effects alter our perception of color. For example, fog mutes the colors of distant objects. Additionally, adjacent colors substantively modify neighboring hues. These observations are not new: Aristotle, Leonardo and Goethe noted these phenomena. Michel-Eugène Chevreul (1786–1889), a 19th-century pigment chemist and director of dye works at the Gobelins textile factory in Paris, became famous for his theory of optical mixing. In *Laws of Simultaneous Color Contrasts* (1839), he stated: "To put a color on a canvas is not only to paint everything that the brush has touched with this color, it is also to apply the complementary color to the surrounding space" [30]. Artists from Eugène Delacroix to Paul Gauguin, Georges Seurat and Josef Albers, to name only a few, either drew on Chevreul's concepts or developed their own perspectives on the perception of simultaneous contrasts and mixture of optical tones.

Third, internal physiological processes determine our color perception. Following from Goethe and Schopenhauer, our perception turns upon what Julia Kristeva speculated, decades ago, to be internal "biophysical" and "biochemical" processes [31]. We perceive colors when light waves or photon particles of different radiation lengths or strengths—the waves in themselves, as Newton understood, are not colored—fall on the retina, the multilayered neuronal membrane that lines the back wall of the eye. Such events cause chemical reactions and nerve excitations to occur in photoreceptors or light-sensing cells, called the cones and rods [32]. These microscopic "filaments" transfer the sensory information via a secondary system of cells to the visual cortex.

Today, scientific and philosophical journals contain numerous articles that address a kaleidoscope of approaches. Drawing on the rich history, many scientists and philosophers "stake out," as Thompson puts it, "extreme positions" [33]; for the most part they divide into two groups. On one side are the "objectivists" and "realists." This group holds that colors are out there; they are "mind-independent" and, as Ian Gold argues, "identical to an 'optical' property of objects such as their *surface spectral reflectance* [SSR], that is, the disposition of objects to selectively reflect light of different wavelengths in different proportions" [34]. More complexly, Alva Nöe argues that phenomenal objectivism "recognizes that . . . colors are not relations between objects and the nervous system. Rather, they depend on relations between objects and viewing conditions" [35]. In contrast, the subjectivists or anti-realists proclaim that there are no colors out there, "only brain-based experiences of colour," eliminating color as a property in the physical world and arguing that physical color is a "metaphysical mistake" [36]. Colors are useful illusions. Citing Mark Johnston, Gold suggests, the "judicious choice" resides somewhere "between those who say that the external world is colored and those who say that the external world is not colored" [37]—relationalists occupy such a territory [38].

What is most interesting is that, as Gary Hatfield explains, "Proponents of all three positions marshal the available scientific evidence in their support"; they all draw on studies of "color constancy" [39]. As Hatfield explains, color constancy turns upon "the ability to develop a stable representation of surface colour under variations in ambient illumination" [40]. It is here that the science moves from the argument between Newton's refrangibility and Goethe's physiology to Thomas Young and Hermann von Helmholtz's trichromatic theory and Ewald (Evald) Hering's post-receptor sensory processing—the latter of which is a rich arena for artistic inquiry.

Becoming Blue

Over the past several decades, a number of interesting studies address the topic of color constancy and why when we enter a room, for example, despite the fact that sunlight shines only on a section, we perceive the walls as having a uniform color [41]. Many theorists discuss this perceptual behavior, making related arguments regarding the redness of tomatoes: Even though the fruit's color changes from the garden to the kitchen, our perception adapts to changes in ambient light, and its redness appears constant. It is on this point that Dorothea Jameson and Leo Hurvich's now "classic" essay contributes insight.

In "From Contrast to Assimilation: In Art and in the Eye," Jameson and Hurvich argue that changes in pupil dilation cannot "compensate for any but a small fraction of the range of illumination levels that control the amount of light imaged on the retina" [42]. Instead, they suggest that we compensate; we learn to expect red tomatoes—not just in different lighting conditions (even though tomatoes do come in a variety of colors). To see color "constancy," we selectively respond to light shifts and we physiologically and psychologically adapt to the environmental and cultural context. Such adaptations have become the subject of artistic inquiry; in this regard, Jameson and Hurvich cite Claude Monet's late-19th-century series of time-based works.

In the late 1800s, Monet painted at least three distinct series of Rouen Cathedral's impressive stone façade, at different times of the day and in various weather conditions. To denote environmental fluctuations, many of his titles include such markers as "in early morning," "in full sun" and "in early afternoon." Through this body of work the artist demonstrated that color perception is dynamic, tied to time and space.

Jameson and Hurvich move from their discussion of Monet's dynamic range to the "sharpening" or "crispening" aspects of perceptual vision. Here, they directly draw on the insights of Hering, a 19th-century physiologist and psychologist, and his understanding of a secondary level of neural cell organization—the interface between the photoreceptor cells and the optic nerve. Hering's insights, however, evolved within a historical context and, at the time, appeared to be a position opposing Young-Helmholtz's.

Hering published his concept of opponent theory in 1892; while it had some intermittent support, scientists rejected it, favoring instead its adversary: the Young-Helmholtz Theory of color perception (sometimes called "Component Theory" or "Trichromatic Theory").

Around 1860, Helmholtz adopted Young's theory that "the sensation of different colours depends on the different frequency of vibration excited by light on the retina" [43]. In 1802, Young reasoned that, while the color spectrum contained an infinite number of prismatic divisions, it was impossible for the retina to maintain an endless number of photoreceptor cell types. Therefore, a limited number of receptors must be able to simulate a broad range of color perception. As Kemp summarizes, just as the theory of primary colors had shown that only three colors were required for the full spectral range, "only three different kinds of receptors are needed in the eye" [44]. Helmholtz expanded on Young's trichromatic system of photoreceptor types, arguing that each cone-type was sensitive to a particular range of visible light, or wavelengths: short (violet), medium (green) and long (red). Hering, however, found this idea lacking and sought to unpack the "riddle" of visual perception further [45].

Hering introduced the idea that a second level of neural architecture played a dominant role in color perception, leading to what Jameson and Hurvich call a "crispening effect" of color. Hering's theories turned from the excitation of cones in the retina to the function of what we know today as the bipolar and ganglion cells. As these cells receive information from the photoreceptor cells, a highly intricate and antagonistic form of post-retinal processing occurs. Hering argued that color perception was a reactive physiological response that followed three "opponent" axes or channels: red-green, blue-yellow, and black-white (chromatic/achromatic). As Jameson and Hurvich put it: "The paired physiological processes are assumed to be opposite and antagonistic in nature and the paired sensory qualities (red-green, yellow-blue and white-black) are also mutually exclusive" [46]. To perceive red, an increase in a chemical reaction must occur, one that is antagonistic and at the expense of perceiving green. In short, Hering suggested that color perception turns upon an activation and deactivation of internal chemical processes. It concerns "the 'learning' aspects of the varied perceptual problems, in terms of physiological mechanisms" [47].

It is interesting to note that in the very decade that Hering published his ideas, Monet painted façades of the Rouen Cathedral, clearly exposing the color constancies that commonly occur during various times of day. While Jameson and Hurvich cite this example, it would appear, however, that Monet had already developed his own variant of "opponent color theory." While the fuzziness of his visualizations varies according to early morning, midday and late afternoon, the crispness of his paintings comes through in his choice of color combinations. Even before the early 1890s, in paintings such as *Impressionism: Sunrise* (1873), but also in many other works, Monet often used two opponent colors: a blue and a yellow-orange pigment.

Jameson and Hurvich were some of the first to realize that Hering's and Helmholtz's positions were not in conflict (provided, as Palmer explains, one overlooks some flaws in Hering's theory) [48]. Hering and Helmholtz were defining different layers of the neural system: The opponent and trichromatic theories explain the multilevel functioning of the physiological mechanism of color perception in humans. More specifically, Hering's ideas led to insights regarding color constancy and explanations pertaining to visual illusions such as color afterimages. Yet fine-tuning continues—some explore not the micro-system within the human substrate but the surface spectral reflectances out there.

Initially, physicalism appears to rehash previous antagonist debates, in that it appears to counter opponent theory. As Alex Byrne puts it, physicalism turns upon the notion that "colours are physical properties of some kind, for example microphysical properties, or reflectances" [49]. Yet many reject physicalism because, like realism and objectivism, it does not appear to account for the physiological perception of colors and, more specifically, color constancy. Nöe, however, argues for a more developed version of the position: Some physicalists, he states, focus upon the "surface spectral reflectance" or the property by which "an object is disposed to reflect a given proportion of incident light at each wavelength in the visible spectrum" [50]. Nöe further adds:

> The physicalist picture, *like that of the phenomenal objectivist*, but unlike that of the subjectivist, accommodates nicely such facts as that we experience the redness of the tomato as a property *of the tomato* and that, when we look at three tomatoes that are the same color, we take it that the tomatoes share a property in common. Physicalism would also seem to be able to account elegantly for the basic facts of color constancy [51].

Although Nöe is critical of physicalism, citing metamerism and other color perception anomalies, Robert Pasnau's provocative argument for "event physicalism" is even more compelling. In "The event of color," Pasnau observes that although

> there are many versions of physicalism, they tend to agree on this basic point: that a particular instance of a color, on the surface of an object, is the enduring microphysical structure that explains why the surface has its distinctive light-reflecting characteristics [52].

Building on this point, Pasnau hypothesizes that light waves do not just bounce off objects to produce the appearance of a color; the specific spectral section of waves are absorbed and split and then the relevant frequencies are reemitted. The result, he states, is

> a complex microphysical event near the surface of the object. If we are to be physicalists regarding color, then we should analyze colors in terms of that event, just as we analyze heat in terms of molecular motion, and sound in terms of vibrations [53].

In his nuanced take, Pasnau invokes the existence of an epidermis-like thickness in which spectral flux occurs: "What [other] physicalists have ignored," he argues, "is that we can distinguish between those standing properties and the events and properties that arise when an object is illuminated." Color, he further proposes, is tied to "events rather than to standing conditions" [54]. Light frequencies energize a surface, inducing a liveliness that is absorbed into a surface and radiated outward. Such invigoration agitates surrounding surfaces and environmental incidents, giving rise to color events or dynamic energized states. Such vibrancy resonates with the physiological density of human vision, photoreceptors and optical interpreter cells. Suddenly, Nöe's analysis begins to bloom: "Environments are codetermined by inhabitants of the environment. The environment is the physical world *as it is inhabited*" [55]; just as colors are in constant flux, so are our perceptions of them. He, unlike current computational theorists who explain vision as an information-processing activity [56], is more open to parallel, more expansive, artistic inquiries of dynamic flux.

For Kurt Schwitters, color oscillates along "color opponent" axis channels: His lover's hair turns from yellow to blue, and the whirling wheels turn from green to red. Seeing color is always about constantly fluctuating "crispness" that, as Matisse also knew, only conditionally stabilizes. For modernist artists, colors were component or opponent forces and "one is not bound to a blue, to a green, or to a red." They are sensuous forces that prowl, synesthetically breaking barriers and material constraints.

Hiorns's crystalline crusts likewise produce such dynamic instability. Absorbed light splits, and the reflected and refracted light is re-encoded within the pixels displayed on my iPad screen. I see the chalkiness of the pigmented surface, yet blue illumination floods my perceptual space. Blue races through my neural system and, to borrow from Michael Taussig, becomes "a total bodily activity" [57]. Color experience "comes across . . . [more as] a presence than a sign, more a force than a code, and more as *calor* [heat]" than hue [58]. Blue is suddenly alive: a combustible mix of attraction and repulsion, seduction and aversion. Its "vivacity," "pure experience" or manyness, *enters* my situation and has an unbinding force that, according to Kristeva, breaks through. A host of personal memories, cultural associations, psychological drives and impulses cascade together. I adapt, yet blue becomes an "ingressive activity:" I breathe in blue and it breathes me out. I involuntarily shade my eyes and barely suppress a full-body shiver—a "seizure." "*He" had me at blue.*

References and Notes

Unedited references as provided by the author.

1. *Marnie*, film, directed by Alfred Hitchcock (1964).

2. J. Goethe, *Goethe's Theory of Colours*, trans. Charles Lock Eastlake (NY: Gordon Press, 1975) #115.

3. Goethe [2] #126.

4. Henri Matisse, *Matisse on Art*, ed. Jack D. Flam (Berkeley CA: Univ. of California Press, 1995) p. 84.

5. Brian Massumi, "Too-Blue: Color-Patch for an Expanded Empiricism," in Brian Massumi, *Parables for the Virtual: Movement, Affect, Sensation,* Chapter 9 (Durham: Duke Univ. Press, 2002) p. 211.

6. Quoted in Massumi [5] p. 293, footnote 15.

7. Arthur Schopenhauer, *On Vision and Colors*, Georg Stahl, ed. and trans. (NY: Princeton Architectural Press, 2010) p. 76.

8. Quoted in Schopenhauer [7], also Goethe [2] p. lv.

9. Martin Kemp, *The Science of Art: Optical themes in western art from Brunelleschi to Seurat* (New Haven: Yale Univ. Press, 1990) p. 261.

10. My title alludes to the inadequacy of words in expressing the palpable sensuousness of color. "He" refers to *Seizure* and its vibrato/physical resonance. Evan Thompson, *Color Vision: A Study in Cognitive Science and the Philosophy of Perception* (New York: Routledge, 1995) p. xii.

11. Rainer Mausfeld, "The perception of material qualities and the internal semantics of the perceptual system," in *Perception beyond Inference,* eds. Liliana Albertazzi et al. (Cambridge MA: MIT Press, 2010) p. 172.

12. Aristotle, *Sense and Sensibilia,* also *On Colours* in *The Complete Works of Aristotle,* ed. Jonathan Barnes (Princeton, NJ: Princeton Univ. Press, 1991) 439b20–440a6.

13. Kemp [9] p. 285.

14. See Isaac Newton, *Opticks*, 4th edition (London: William Innis, 1730) pp. 2–64.

15. See Newton's letter dated 1671–1672: <www.newtonproject.sussex.ac.uk/view/texts/normalized/NATP00006> (accessed 28 December 28, 2012).

16. Kemp [9] p. 286.

17. Stahl in Schopenhauer [7] p. 13.

18. Kemp introduces the debate between Newton's particle theory (which later became known as corpuscular theory) and Christiaan Huygens's wave theory. See Kemp [9], pp. 287–293. Today, science acknowledges wave and, rather than corpuscular, photon theory (after Albert Einstein's quantum theory of light).

19. See Kemp [9] pp. 285–286. Kemp also lists oversights in Newton's argument, including his failure to distinguish between additive and subtractive mixing.

20. For a description of Goethe's "experiment," see Michel Meulders, *Helmholtz: From Enlightenment to Neuroscience*, trans. Laurence Garey (Cambridge, MA: MIT Press, 2010) pp. 119–121.

21. Goethe [2] p. xliii.

22. Schopenhauer [7] p. 59.

23. Schopenhauer [7] pp. 58–59.

24. Schopenhauer [7] p. 75.

25. Joseph Levine, quoted in Meulders [20] p. 123.

26. Levine [25] 277.

27. Levine [25] 276.

28. Stephen Palmer, *Vision Science: Photons to Phenomenology* (Cambridge MA: MIT Press, 1999) p. 15.

29. Levine [25] 272.

30. Quoted in Meulders [20] p. 123.

31. Julia Kristeva, *Desire in Language: A Semiotic Approach to Literature and Art*, Thomas Gora et al. trans. (NY: Columbia Univ. Press, 1980) p. 222.

32. Cones and rods serve different functions: cones are photoreceptor cells responsible for high levels of light (photopic vision), whereas rods are for lower light levels (scotopic vision).

33. Thompson [10] p. xi.

34. Ian Gold, "Dispositions and the Central Problem of Color," in *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition* vol. 93, no. 1, p. 22 (1999).

35. Alva Nöe, *Action in Perception* (Cambridge: MIT Press, 2004) p. 148.

36. Thompson [10] p. xi.

37. Gold [34] p. 21.

38. See Gary Hatfield, "Objectivity and Subjectivity Revisited," in *Colour Perception*, eds., Rainer Mausfeld and Dieter Heyer (London: Oxford Univ. Press, 2003) pp. 187–202.

39. Hatfield [38] p. 188.

40. Hatfield [38] p. 189.

41. See Faber Birren, "Color Perception in Art: Beyond the Eye into the Brain" *Leonardo*, vol. 9, pp. 105–110 (1976).

42. Dorothea Jameson and Leo Hurvich, "From Contrast to Assimilation: In Art and in the Eye," *Leonardo* vol. 8, p. 125 (1975).

43. Thomas Young, "The Bakerian Lecture: On the Theory of Light and Colours," *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London*, vol. 1 (1800–1814) p. 64.

44. Kemp [9] p. 320.

45. Ewald Hering, "On the Theory of Nerve-Activity," *The Monist,* vol. 10, no. 2, pp. 168 (1900).

46. Hurvich and Jameson, "Perspectives: Human Color Perception: An Essay Review" *American Scientist*, vol. 57, no. 1, p. 152 (1969).

47. Hurvich and Jameson [46].

48. Palmer [28] pp. 110–111.

49. Alex Byrne, "Colour Vision, Philosophical Issues About," *Encyclopedia of Cognitive Science,* Macmillan Reference, p. 35 (2000).

50. Nöe [35] p. 150.

51. Nöe [35] p. 151.

52. Robert Pasnau, "The event of color," *Philosophy Studies* 142 (2009) p. 354.

53. Pasnau [52] pp. 353–354.

54. Pasnau [52] p. 356.

55. Nöe [35] p. 155.

56. See Palmer [28] pp. 41–42.

57. Michael Taussig, *What Color is the Sacred* (Chicago: Univ. of Chicago Press, 2009) p. 6.

58. Taussig [57] p. 6.

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