WHERE 'THINGS GO THE OTHER WAY': THE STEREOCHEMISTRY OF LEWIS CARROLL'S LOOKING-GLASS WORLD

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Abstract

In the opening scene of *Through the Looking-Glass,* Alice asks a feline friend, 'How would you like to live in Looking-Glass House, Kitty? I wonder if they'd give you milk in there? Perhaps Looking-Glass milk isn't good to drink?' Alice's speculation regarding the potability of Looking-Glass milk has long been considered by chemists to be Carroll's subtle reference to *stereoisomers.* Discovered by Louis Pasteur in 1848, stereoisomers are molecules that contain the same number and kinds of atoms but differ from each other in spatial orientation. The stereoisomers of lactose ($C_{12}H_{22}O_{11}$) in milk exist as non-superimposable mirror images of each other; therefore, the milk Alice would drink in the Looking-Glass House is of the opposite three-dimensional configuration than the milk of the 'regular' world, and for that reason, Carroll wonders if the former might produce an insalubrious, rather than healthful, effect. While much has been written about this particular representation of stereoisomerism in *Through the Looking-Glass,* scientists and literary scholars alike have failed to recognize the potential chemical subtext of the story's other mirror images. In this paper, I will argue that manifestations of stereoisomerism are not just confined to the looking-glass milk scene, and that the ways in which Carroll explores issues of doubling, inversion, and reversibility in the 'mirror world' suggest a far more elaborate contemplation of the implications of stereoisomers. Characters such as Tweedledum and Tweedledee and Humpty Dumpty, the notion of 'unbirthdays', and even to some extent Carroll's pseudonymity reflect the author's fascination with, and at times anxiety about ,the idea of a dual chemical existence, a world in which every person, place, and thing comprises two like yet non-superimposable forms.

In the opening scene of Lewis Carroll's *Through the Looking Glass*, a perturbed Alice tells her black kitten that if 'she's not good directly', Alice shall 'put [her] through into Looking-Glass House'. And, 'how', Alice then asks her cat, 'would you like *that*?'1 The Looking-Glass House, as one might infer, refers to Alice's home as it is reflected in the Looking-Glass, the house that is inside the mirror. Still dissatisfied with her cat's behavior, Alice continues to goad her feline friend with questions about the relative quality of a Looking-Glass existence: 'How would you like to live in Looking-Glass House, Kitty? I wonder if they'd give you milk in there? Perhaps Looking-Glass milk isn't good to drink?' (p. 131). Alice's statements may appear initially to be merely innocent musings, but, like many of the seemingly fanciful features of Carroll's stories, this little speech has more serious, even darker

1 Lewis Carroll, *Alice's Adventures in Wonderland & Through the Looking-Glass,* ed. Horace Gregory (New York: Penguin Putnam), p. 130. Further references to this edition are given after quotations in the text.

resonances.

Literary scholars and chemists alike have long considered Alice's speculation regarding the potability of looking-glass milk as Carroll's unconscious, indeliberate reference to a certain type of chemical compound discovered earlier in the nineteenth century. Four years before Carroll was born, a German scientist by the name of Friedrich Wöhler noticed that the compound cyanic acid, though composed of the same number and types of atoms as another compound, fulminic acid, possessed different properties. Such compounds, which have identical chemical formulas but vary in chemical properties, would eventually be called *isomers*.2

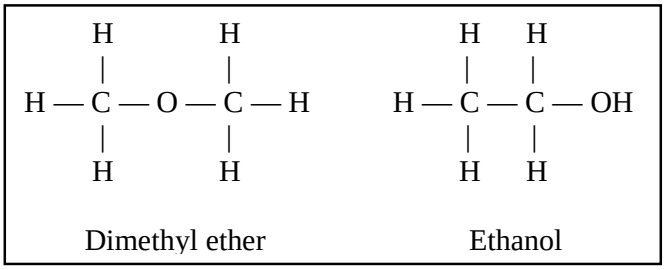

Figure 1: Isomers

Wöhler's 1828 finding was soon followed by similar discoveries by a number of other scientists, including Louis Pasteur, who in 1848 wrote about a particular type of isomer called *stereoisomers*, molecules that contain the same number and kinds of atoms but differ from each other in spatial orientation. Stereoisomers are the multiple physical forms that arise from one chemical formula; the hydrocarbon C_4H_{10}, for example, comprises two stereoisomeric forms, *cis*-two-butene and *trans*-two-butene.

Some stereoisomers exist as mirror images of each other; these compounds have at least one *asymmetric carbon*, that is to say, a carbon atom that is attached to four different atoms or groups of atoms (see image below). The presence of an asymmetric carbon renders the stereoisomers non-superimposable, and for that reason they are often metaphorized as the 'left-hand' and 'right-hand' versions of a molecule, with one stereoisomer oriented clock-wise and the other counter-wise.3

2 A *chemical formula* uses numbers and symbols (e.g. *O* for oxygen and *H* for hydrogen) to describe a compound's chemical composition (that is to say, the numbers and types of atoms it contains). For example, H_2O, the chemical formula for water, contains two atoms of hydrogen and one atom of oxygen.

3 The orientation of a stereoisomer refers to which direction (clockwise or counter-clockwise) it rotates the plane of polarization in a beam of light.

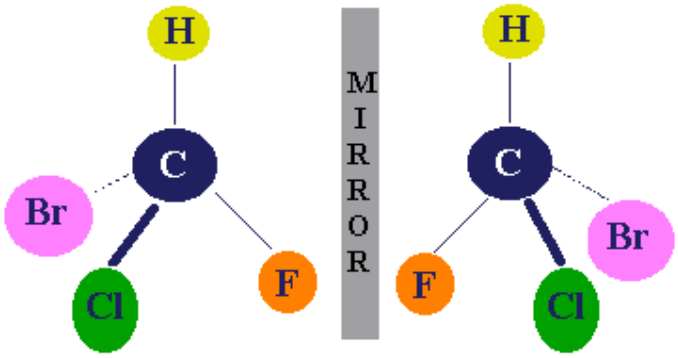

Figure 2: Stereoisomers of CHBrClF

The stereoisomers of lactose ($C_{12}H_{22}O_{11}$) in milk fit this description; therefore, the milk Alice would drink in the Looking-Glass world is of the opposite three-dimensional configuration than the milk in what this essay will henceforth refer to as the 'regular' world.

While Gardner and a few other critics have casually noted this particular representation of stereoisomerism in the story, neither science nor literary scholars have embarked on a more comprehensive stereochemical analysis of *Through the Looking-Glass*.4 Furthermore, the criticism that does exist on the prevalence of mirror images in the story does not recognize or too readily dismisses the possibility of a chemical subtext. In this paper, I will argue that manifestations of stereoisomerism in *Through the Looking-Glass* are not solely confined to the Looking-Glass milk scene, and that the issues of doubling, inversion, and reversibility Carroll explores through the 'mirror world' suggest a far more elaborate contemplation of the implications of stereoisomers. Characters such as Tweedledum and Tweedledee and Humpty Dumpty, the notion of 'unbirthdays', and even to some extent Carroll's pseudonymity reflect the author's fascination with, and at times anxiety about, the idea of a dual chemical existence, a world in which every organic substance comprises two non-superimposable, mirror forms, or as I will call them, *stereoisomeric doubles.*

This stereochemical analysis will first explore the author's relationship with those sciences that most informed his conceptualization of mirror images, chemistry and optics. I will next examine the representations and implications of doubles (stereoisomeric and non-stereoisomeric) in *Through the Looking-Glass* before moving on to consider how in light of the author's issues with pseudonymity, chemical duality was particularly relevant to Lewis Carroll (and Charles Lutwidge

4 Martin Gardner asserts that milk exists as stereoisomers but posits an incorrect timeline: 'it was not until several years after the publication of *Through the Looking-Glass* that stereochemistry found positive evidence that organic substances had an asymmetric arrangement of atoms'. *The Annotated Alice: Alice's Adventures in Wonderland & Through the Looking-Glass* (New York: Forum Books, 1960), p.183.

Dodgson).

The Science of Lewis Carroll

As mathematics lecturer at Oxford and author of several publications on logic, Carroll regularly drew upon these disciplines when penning *Alice in Wonderland* and *Through the Looking-Glass*. Critics in turn have been ready and willing to explore and accept the influence of the author's scholarly expertise on the content and construction of his work. But Carroll's academic interests were hardly confined to the syllogisms or word ladders or the determinants of square matrices. His fascination with gadgets, his fervid responses to vivisection, and his opposition to anti-vaccination campaigns certainly point to a sustained interest and engagement with other scientific disciplines, including, but not limited to, physics, medicine, and biology.

In their critical treatment of *Through the Looking-Glass,* however, scholars still seem to assume that Carroll had little to no knowledge of chemistry and, more importantly, was virtually unaware of recent developments in the field. In his annotation to the infamous milk scene, Gardner writes that 'Alice's speculation about looking-glass milk has a significance greater than Carroll suspected', thus eliding the possibility of a chemical component to the author's representation.5 Likewise, science critic Karen Schmidt's claim that 'the imaginative Lewis Carroll cooked up the possibility [that chemicals could come in mirror-image pairs]', assumes that Carroll, who was writing *Through the Looking Glass* in the early 1870s, was ignorant of Pasteur's work on stereoisomers done more than twenty years earlier.6 Although Carroll was probably not intimately acquainted with the nuances of Pasteur's findings, it is very likely that he had at least a cursory understanding of stereoisomers given that his favourite (and most famous) pastime required more than just a casual familiarity with chemistry. Indeed, of all Carroll's 'amateur' disciplines, that is to say those he did not pursue as a professional academic, chemistry figured most prominently in the author's every day life because a solid knowledge of its basic principles was necessary for successful picture-taking. As a photographer, Carroll developed film using the wet collodion process, which required careful and precise mixing of chemicals. Thomas Hardwich's 1883 *Manual of Photographic Chemistry, Theoretical and Practical* accordingly contains twenty-odd pages of instructions on how to prepare correctly the nitro-sulfuric acid, describing in detail how the slightest alteration in ingredient proportions renders the entire process ineffective.7

5 Gardner, p. 183.
6 Karen Schmidt, 'Mirror-Image Molecules', *Science News,* 143 (1993), 348–35 (p. 348).
7 Despite its many challenges, the wet collodion process was heartily embraced by Carroll and nineteenth-century photographers because it produced images that were clear and delicate, and unlike daguerreotypes, infinitely and easily replicable.

The contents of Carroll's personal library at the time of his death suggest that the vagaries of the wet collodion photography prompted the author to do further research on the composition of chemical compounds and that in the process he read about (perhaps not for the first time) the theory of isomerism. Carroll's science books included William Thomas Brande's *A Dictionary of Science, Literature, and Art* (1842); William Allen Miller's *Elements of Chemistry, Theoretical and Practical* (1855–1857) in three volumes, *Chemical Physics, Inorganic Chemistry,* and *Organic Chemistry)* and John Sadler's *An Explanation of Terms Used in Chemistry* (1804).8 All of these books contain information on chemical bonding and compound structures, but Brande's *Dictionary* is particularly relevant for its entry on *isomers.*9 While Carroll's ready access to these texts makes it likely that they at least in part served as the foundation for his scientific knowledge, these books should not, however, be considered the only means by which the author may have become familiar with stereochemistry. The development of this field was contemporaneous with the author's own science and mathematics education; indeed, the discursive history of isomerism in many ways runs parallel to Carroll's lifetime.

In the early nineteenth century, scientists generally thought that every chemical compound had its own unique chemical formula. This assumption was based in large part on the research of eighteenth-century scholars like Antoine Lavoisier, who in his 1789 *Traité Élémentaire de Chimie* ('Elementary Treatise on Chemistry', translated 1790) described his attempts (mostly unsuccessful) to determine what he considered to be the unique proportions of certain elements in various compounds.10 In 1809, Joseph Gay-Lussac improved upon Lavoisier's work on chemical formulas when he found that in the formation of water a certain volume of gaseous hydrogen is needed to react with a certain volume of gaseous water.11 The fact that volumes of combining gases occurred in simple ratios confirmed the findings of John Dalton, who one year prior had proposed in *A New System of Chemical Philosophy* that the relative numbers of atoms of elements in chemical compounds can be expressed in whole number ratios. Both Dalton and Gay-Lussac conceived of these atomic ratios as differentiating one compound from another but did not consider that a single ratio (as expressed through one chemical formula) could describe two different chemical compounds. As previously mentioned, it was Friedrich Wöhler who arrived at this conclusion in 1824 when he discovered his analysis of cyanic acid (chemical formula HCNO) was identical to an analysis of fulminic acid (*also* chemical formula HCNO)

8 Charlie Lovett, *Lewis Carroll Among His Books: A Descriptive Catalogue of the Private Library of Charles L. Dodgson* (Jefferson, NC: McFarland, 2005), pp. 54, 210, 269.

9 'Compounds which contain the same elements in the same ratio, and yet exhibit distinct chemical qualities, are said to be *isomeric*. The cyanic and fulminic acids are isomeric compounds of nitrogen, oxygen, and carbon. The distinctions thus arising are probably referable to the different ways in which the same elementary atoms are gropued [*sic*] in the compound'. William Brande, *A Dictionary of Science, Literature and Art* (London: Longmans, 1842), p. 713.

10 F.J. Moore. *A History of Chemistry.* (New York: McGraw-Hill, 1918), pp. 50–2.

11 This finding formed the basis of Gay-Lussac's 'law of combining volumes' and was published in his 'Memoir on the Combination of Gaseous Substances with Each Other' (1809).

published a year earlier in the journal *Annales de Chemie* (edited ironically by Gay-Lussac). Author of the fulminic acid analysis Justus Liebig initially accused Wöhler of falsifying his results, but through laboratory testing the former confirmed the latter's findings. Neither Liebig nor Wöhler, however, could immediately say why two distinct compounds with different chemical properties contained the same numbers and types of atoms.12 The correct explanation came from Swedish chemist Jöns Berzelius, who in his 1832 *Jahresbericht*13 outlined how one chemical formula could yield multiple structural arrangements of atoms (isomers) and hence multiple compounds with different properties.14 In 1848, Pasteur elaborated on this theory of isomerism while giving a paper to the Paris Academy of Sciences. In this landmark lecture, he noted how racemic acid comprised two types of crystals that under a microscope appeared to be mirror images of each other. Upon further testing, Pasteur correctly concluded that racemic acid exists as two isomers, one that rotates plane-polarized light clockwise and the other that rotates light counter-clockwise. This subtype of isomers would eventually be known as *stereoisomers.*

Given that such theoretical developments were well publicized in academic as well as mainstream venues, Carroll, as a frequent contributor to (and reader of) a wide range of periodicals, probably encountered the concept of stereoisomerism at multiple points throughout his life and in a number of different sources. Textual references to mirror-image molecules may have initially attracted Carroll's attention because of his fascination with looking-glasses. Like many Victorians, Carroll was intrigued by optical devices as well as instruments of visual perception, and regularly experimented with mirror reversals. To entertain himself and his young friends, Carroll composed letters in 'mirror-writing' that could only be read by starting at the last word and reading to the first and drew funny pictures that changed once turned upside-down.15 The inspiration for *Through the Looking-Glass* was, in fact, a very large mirror that sat above the drawing room fireplace at Hetton Lawn, the home of Alice Liddell's grandmother. After visiting Alice and her sisters there in early April of 1866, Carroll may have fantasized about what might happen should one climb up onto the mantelpiece and go through to other side of the mirror.16

In imagining the mirror to be traversable, Carroll imposed on it one of the definitive properties of another type of 'glass' with which he was unusually preoccupied, the photographic lens. The lens can be thought of as the antithesis of mirror, for whereas light passes through a lens and emerges "bent" on the other side (*refraction*), it hits and bounces away from a mirror (*reflection*). Refraction causes an

12 Soledad Esteban, 'Liebig–Wöhler Controversy and the Concept of Isomerism', *Journal of Chemical Education,* 85 (2008), p. 1202

13 The *Jahresbericht,* or annual report on advances in the field of chemistry and physics, was written by Berzelius and published through the Stockholm Academy. From 1821 to 1848 Berzelius published 27 volumes of the *Jahresbericht.*

14 Henry M. Leicester and Herbert S. Klickstein, *A Source Book in Chemistry, 1400–1900* (Cambridge, MA: Harvard University Press, 1969), p. 264.

15 Gardner, p. 182.

16 Morton N. Cohen, *Lewis Carroll: A Biography.* (New York: Alfred A. Knopf, 1995), p. 96.

object on the regular side of a lens to appear upside down on the other side. For that reason, the lens of the human eye produces an upside-down image; however, because we are neurologically programmed to deal with a 'right-side up' world, the brain 'flips' the image. Hence what we 'see' is actually the brain's 180-degree readjustment.

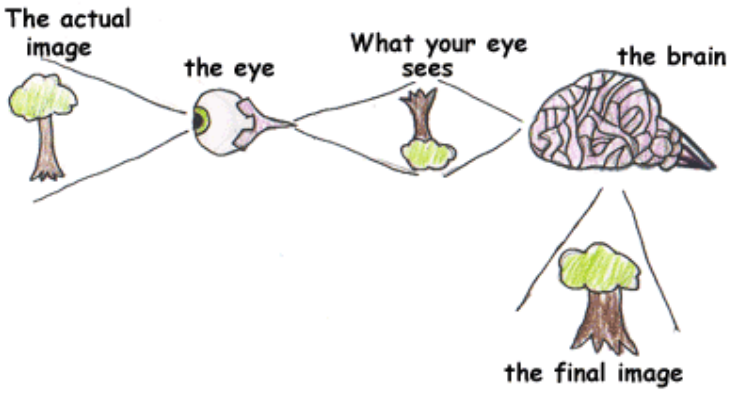

Figure 3: How We 'See'

As early as second century AD, Greek physician and philosopher Galen of Pergamun recognized this disconnect between ocular input and visual perception but could not offer a precise mechanism for image reversal. The invention of the *camera obscura* around 1000 AD forged the initial epistemological link between the eye and the photographic lens and gave rise to further debate as to the neurological origins of image reversal.17 The earliest prototype of the camera, the camera obscura produces an upside-down image by streaming light through a small hole in a darkened room or box. Its impact on the development of visual theory cannot be overstated, for as Christopher Otter notes, 'it affected the scientific imagination so greatly that by the seventeenth century it had become the model for the eye'.18 Accordingly, in his 1690 'Essay Concerning Human Understanding' John Locke highlighted the connection between human vision and photography by analogizing the darkened space of the camera obscura to the human mind, into which external images of the outside world must be conveyed.

What Locke notably did not address was the fact that the images produced in the dark room of the camera obscura (and by extension in the human mind) required neurological mediation as to register them 'right side up'. In 1601, Johannes Kepler

17 The earliest recorded construction and analysis of the camera obscura occurs in *Kitab al-Manazir,* written by Ibn al-Haytham. This work was translated into Latin (*Objectiva)* in the thirteenth century. Nicholas J. Wade and Stanley Finger, 'The eye as an optical instrument: from camera obscura to Helmholtz's perspective', *Perception* 30 (2001) 1157–77 (p. 1159).

18 Chris Otter, *The Victorian Eye: A Political History of Light and Vision in Britain, 1800–1910* (Chicago: University of Chicago Press, 2008), p. 26.

had argued in his *Astronomiae Pars Optica* (*The Optical Part of Astronomy*) that the lens of the human eye projects an inverted image on the human retina, but it was not until the nineteenth century that scientists arrived at a more precise understanding of the sensory systems involved in 'flipping' that image. In 1809, Franz Josef Gall proposed in *Recherches Sur le Système Nerveux* (*Research on the Nervous System*) that all physical functions were localized within the brain and more relevantly, that one of the three sections of the cerebral cortex was responsible for vision.19 Pierre Marie Flourens further established in 1824 that sight depends on the integrity of the cerebral cortex when he showed that removal of this organ in a bird causes blindness. With the 1833 publication of *Handbuch der Physiologie* (*Elements of Physiology*),20 Johannes Müller laid the groundwork for specifying the physiological link between the eye and the brain by introducing the idea that sensations (sight, for example) are associated with 'specific nerve energies'.21 This hypothesis presaged later work on the role of the optic nerve in transmitting information to the cerebral cortex.

The work of Gall, Flourens, Müller, and other scientists have led many critics to identify the Victorian Era as a time in which both scholars and lay people were uniquely interested in visual perception. R. Steven Turner notes that literature on vision studies flourished during this period, growing almost exponentially between the years 1840 and 1844 and 1890 and 1894. Jonathan Cary has further argued that flurry of optical developments in the first half of the nineteenth century gave rise to a 'visual culture of modernity' that involved new ways of seeing**.**22 Central to the development of this new visual culture were devices like the camera and the looking-glass, which alternately replicated and opposed the work of the human eye. For in contrast to the refracted, upside-down image produced by the lens of a camera or an eyeball, the reflected image produced by the mirror is right-side up but reverse in orientation.

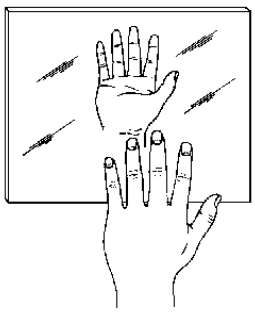

Figure 4: Mirror-Image of Human Hand

19 Zola-Morgan, S., 'Localization of Brain Function: The Legacy of Franz Joseph Gall (1758–1828)', *Annual Review of Neuroscience*, 18 (1995), p. 365.
20 An English edition of Muller's work translated by William Bayly was published in London in 1839.
21 Laura Otis, *Müller's Lab* (Oxford University Press, 2007), pp. 7–10.
22 Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge, MA: MIT Press, 1990).

Because, as Crary further argues, 'an analysis of vision gives crucial insight into the way Victorians constructed experience', it is beneficial to examine carefully why in *Through the Looking-Glass* Carroll focused on 'mirror' rather than 'lens' images.23 In producing refracted as opposed to reflected images, the looking-glass provides an opposite perspective to that afforded by the human eye and, in so doing, makes available an alternate yet scientifically sanctioned world. Given that the contents of this world are derived from and adhere to scientific (specifically, optical) principles, the narratives that emerge from it can be considered more along the lines of science fiction rather than fantasy. Writing about Looking-Glass people, places, and things was thus both alluring and challenging for Carroll, who, as an author, must not and could not rely solely on his own imagination to construct the mirror world.

In *Through the Looking-Glass,* Carroll's decision to privilege reflection over refraction, the world of the mirror over the world of the lens is represented early in text through Alice's choice of punishment for her troublesome pet. 'When I saw all the mischief you had been doing', Alice warns the black kitten, 'I was very nearly opening the window, and putting you out into the snow!' (p. 128). Alice threatens the black kitten with the frosty world beyond the window, but when it continues to misbehave 'to punish it she [holds] it up to the Looking-Glass, that it might see how sulky it was' (p. 130). As Alice forces Kitty to face her naughty self in the mirror, she realizes the mirror, like the window, might serve as a threshold and begins to enumerate 'all her ideas about the Looking-Glass House' (p. 131). The Looking-Glass House, specifically the Looking-Glass drawing-room, is simultaneously foreign and familiar to Alice, who knows that it is 'just the same as our drawing-room, only the things go the *other* way' (p. 131). Her confidence in this assertion comes from empirical evidence; having 'held up one of [her] books to glass', she knows that in the Looking-Glass world the 'books are something like our books, only the words go the *wrong* way' (p. 131; italics mine).

Alice's conflation of *wrong* and *other* in this opening scene lays the groundwork for the complex consideration that follows in *Through the Looking-Glass* as to the possibility that stereoisomeric doubles correlate with moral binaries. When Alice steps into the Looking-Glass, she crosses over into a scientifically Other world, one that mimics yet ultimately deviates chemically from the regular world in a way that is nonsensical, confusing, and 'wrong' to outsiders like Alice, but rational and reassuring to its inhabitants who operate under a different set of rules and assumptions. Cohen calls this world a 'mysterious place', where 'even the laws of nature, law of gravity, for instance do not work as they should', but this description is misleading. Laws of nature are working the way they 'should', but in the Looking-Glass World, that way is unfamiliar and unconventional. Because Carroll does not believe there is a 'right' way in which laws of nature 'should' operate, he uses

23 Carol T. Christ and John O. Jordan, 'Introduction', in *Victorian Literature and the Victorian Visual Imagination* (Berkeley: University of California Press, 1995), p. xx.

stereoisomeric doubles, as well as the other Looking-Glass people, animals, and institutions Alice encounters, to disrupt her and the reader's sense of order, balance, and continuity in a way that causes both to rethink their conceptions.

Two By Two In *Through the Looking-Glass*

Carroll's preoccupation with doubles (stereoisomeric or otherwise) becomes quickly apparent in *Through the Looking-Glass*, which begins, 'One thing was certain, that the *white* kitten had had nothing to do with it — it was the black kitten's fault entirely'(p. 128). In emphasizing the singularity of this instance, Carroll implicitly posits all else but this "one thing" as unfixed and undetermined. Certainty is indeed a scarce commodity in the Looking-Glass World, where things mutate without rhyme or reason, or, at least, not with a rhyme or reason to which Alice is accustomed. Here, however, certainty emerges with regard to the black kitten and the white kitten, phenotypic opposites that represent an optical dichotomy familiar to Victorian photographers, scientists, and certainly to Lewis Carroll. The visible light spectrum, first experimentally produced by Newton in 1666, has at its polar ends *white* and *black*, with whiteness indicating the presence of light and blackness, its total absence.

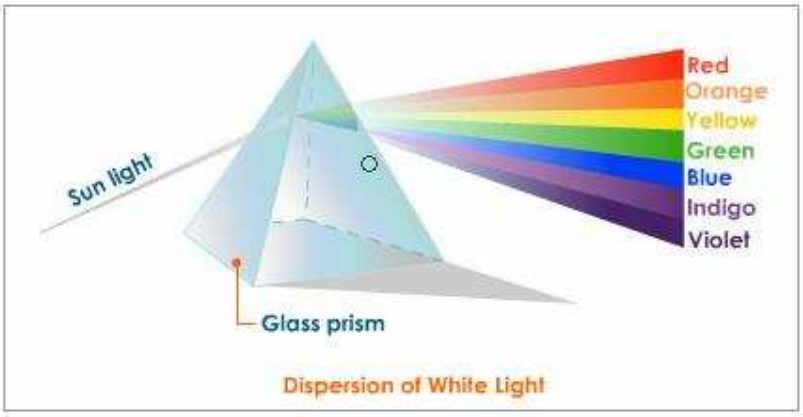

Figure 5: Visible Light Spectrum

The white kitten and black kitten can thus be considered as symbols of light and shadow, respectively, antithetical scientific phenomena that are produced by shining light through a prism, a triangular glass object that *refracts* light. In this way, the black kitten and white kitten initially appear to be *lens* rather than *mirror* doubles.

But the syntactic structure of this first sentence as well as the 'certainty' of the black kitten's guilt suggests that the kittens may be figured as mirror doubles as well. In separating one part of the sentence from the other, the dash serves as a syntactical barrier; furthermore, because this barrier is oriented around the 'it' (the unravelling of the ball of wool) and each part of the sentence is similar but not identical to the other,

one might think of the dash as a figurative looking-glass that separates the *actual* from the *reflected,* the regular world from the mirror world. This syntactical division also explains why innocence and culpability are mutually exclusive in the case of the white kitten and the black kitten. The plane of the mirror denies the white kitten access to 'it', that is to say the *actual* ball of wool, so the black cat must be *entirely* at fault. Since as mirror doubles the cats literally cannot share the crime, they cannot share the blame.

The separation of the black kitten from the white kitten within the space of the sentence likewise represents (or reflects) their physical separation within the space of Alice's drawing room. As Alice points out, because 'white kitten had been having its face washed by the old cat for the last quarter of an hour', it '*couldn't* have had any hand in the mischief' (p. 127). Carroll's use of synecdoche here further supports a conceptualization of the cats as mirror doubles, for as previously noted, the relationship between stereoisomers was regularly metaphorized as a set of human hands, which are themselves non-superimposable mirror images. Describing the white kitten as having had no 'hand' in the mischief is not only amusing in its literal physical disjunction (the cat really had no *paw* in the mischief) but also suggestive of the chemical subtext to the representation of these feline doubles.

Although Alice's choice of punishment for the black kitten (reflection as opposed to defenestration) signals Carroll's decision to privilege the world of the mirror over the world of the lens, the kittens themselves are neither exclusively lens nor mirror images. Rather, they are liminal figures and represent the space between the two worlds. These doubles are similar in function to another optical hybrid, the Looking-Glass, which though opaque becomes momentarily transparent upon Alice fantasizing: 'Let's pretend the glass has got all soft like, gauze, so that we can get through. Why, it's turning into a sort of mist now, I declare! It'll be easy enough to get through' (p. 131). With this literal and figurative turn to the world beyond the kittens and the Looking-Glass, Carroll leaves behind the world of the lens, that is to say, the regular world, and shifts to examining doubles that are exclusively stereoisomeric mirror images.

This transition is marked by the Looking-Glass milk debate. When Carroll was writing *Through the Looking Glass,* scientists had not yet discovered the two isomers of lactose, but the idea that this compound (and by extension, milk) might exist in mirror forms was not lost on the author. Nor was the possibility that because Looking-Glass lactose 'went the other way' with regards to the orientation of regular lactose, the properties of the former would be the reverse of those of the latter. Looking-Glass milk would be harmful, not healthful, terrible, not tasty, and therefore not good to drink. In the twentieth century, scientists would confirm Carroll's hypothesis that a single compound may exist in 'good' and 'bad' isomeric forms, most famously in the case of the now banned drug thalidomide.24 With regards to lactose,

24 Of the isomers of thalidomide, one significantly alleviates morning sickness and another causes serious birth

we now know that it does not exist as 'good' and 'bad' isomeric forms. Both isomers of lactose are digestible; thus, Alice's hesitant prediction is incorrect.

That Alice ultimately refrains from imbibing the milk that 'perhaps isn't good to drink?', suggests that Carroll, at least initially, imagined stereoisomeric doubles as comprising 'good' and 'bad' forms. This idea that a person or thing can exist in two compositionally identical but functionally different forms (one helpful, the other harmful; one good, the other bad) certainly did not originate with Carroll, for dark doubles and evil twin figures abound in nineteenth-century literature, with *Jane Eyre* and *Frankenstein* being salient examples. But what is innovative, I would argue, about the doubles that occur in *Through the Looking Glass* is that their foundation is chemical rather than psychological. While the psychological double is most often a fantastic representation of a character's repressed desires or unconscious emotions, the stereoisomeric double is a specimen from a world in which alternate chemical forms are unavoidable natural phenomena. As opposed to being a 'literary, specifically fictional device for articulating the experience of self-division', the stereoisomeric double is a scientific, realistic device for expressing the experience of self-alternity.25

Stereoisomeric doubles provided Carroll a means by which to imagine and explore a world in which each person and thing existed in two chemical forms, each with its own distinguishing properties. Carroll's uncertainty about the implications of such doubling is reflected in Alice's uncertainty regarding the quality of Looking-Glass milk. Although in this scene Carroll seems to deem one form of milk 'good' and the other 'bad', this characterization should in no way be seen as the author's universal judgment on mirror forms. The increasingly complicated relationships between the sets of stereoisomeric doubles that follow suggest Carroll understood the ramifications of chemical duality, and indeed, human duality, to be infinitely complex.

Stereoisomeric Doubling in the Mirror World

Couples, pairs, and twosomes are frequent features in the world behind the Looking-Glass, and one must look carefully for those doubles that are specifically stereoisomeric in character. Some of Carroll's references to stereoisomerism are subtle, as, for example, the brief mention in the White Knight's Song. To comfort a sad-looking Alice, the White Knight presents her with a ballad, the last verse of which includes the line, 'If e'er by chance I madly squeeze a right-hand foot / Into a left-hand shoe / I weep, for it reminds me so / Of that old man I used to know who seemed distracted with his woe' (p. 217). Gardner identifies the White Knight's

defects.

25 John Herdman, *The Double in Nineteenth-Century Fiction* (London: Macmillan Press, 1990), p. 2.

mention of squeezing a right-hand foot into a left-hand shoe as another example of the sort of left-right reversal that occurs in the looking-glass world.26 To Gardner's observation, I would add that when Carroll emphasizes the fear and frustration that arises when one tries to superimpose the non-superimposable (that is to say, the right foot and the left shoe), he is imagining the perils of living in a dual chemical world in which one no longer could recognize the small differences between two otherwise identical objects, and, as a result, not understand why one served a different purpose than the other. With this reference to right-hand feet and left-hand shoes, Carroll is also asserting that any determination regarding the vice or virtue of respective stereoisomeric doubles may be context dependent. Just as the foot that is right proves 'wrong' when placed in the left shoe, so too may Looking-Glass milk prove harmful when consumed by a regular girl.

A second, more extensive representation of stereoisomeric doubles can be seen in Alice's encounter with the Tweedledum and Tweedledee. Although they are nearly compositionally identical in the sense that their visages and bodies are alike, Tweedledum and Tweedledee are not clones. 'Alice knew which was which,' Carroll writes, 'because one of them had "DUM" embroidered on his collar, and the other "DEE"'. Alice then supposes that 'they've each got "TWEEDLE" round at the back of the collar' (p. 159). As in the Looking-Glass milk scene, Alice's musings signal Carroll's imposition of a chemical subtext. If Tweedledum and Tweedledee do, in fact, have TWEEDLE embroidered at the back of their collars, then we can think of the plane of the mirror separating them at their backs, rendering them non-imposable mirror images.

In addition to this material marker, an old song also relates the stereoisomeric character of Tweedledum and Tweedledee and helps Alice know which is which, for as she recalls, 'Tweedledum and Tweedledee / Agreed to have a battle; / For Tweedledum said Tweedledee / Had spoiled his nice new rattle' (p. 160). By describing Tweedledum as in possession of a rattle, Carroll implies his ability *to rattle*, a property Tweedledee, despite his extreme physical similarity to Tweedledum, lacks. Tweedledee's attempt to destroy Tweedledum's rattle (rather than just use it himself) represents the sort of anxiety and/or discomfort Carroll imagines may ensue with the discovery of stereoisomeric difference, that physical and structural identicality does not correspond to like behaviours and capabilities.

Tweedledum and Tweedledee's near battle over the maligned rattle also suggests Carroll was uncertain as to the tenability of two stereoisomers occupying the same space. Looking-Glass milk and regular milk can exist without conflict because they are separated in their respective worlds by the plane of the mirror. However, in the case of Tweedledum and Tweedledee, worlds have seemingly collided; either Tweedledum or Tweedledee has migrated from the regular to the Looking-Glass world and dissension inevitably arises as they discover they are not one in the same.

26 Gardner, p. 181.

Although Carroll ultimately forecloses the possibility of violent conflict by allowing the crow to intervene as per the plot of the nursery rhyme, the threat that one stereoisomeric double may dominate or destroy the other still remains.27

The most complex representation of stereoisomeric doubling can be seen in Alice's interactions with Humpty Dumpty. Alice purchases the egg that grows to become Humpty Dumpty from the shopkeeper Sheep, who originally offers her 1 egg for fivepence farthing and 2 eggs for twopence. 'Two are cheaper than one?', asks Alice in response to this offer, to which the Sheep replies, 'Only you *must* eat them both, if you buy two' (p. 182). The fact that customers in the Looking-Glass world are financially incentivized to buy eggs in pairs, as well as instructed to consume them in the same fashion, suggests the eggs as stereoisomeric doubles. The eggs are seemingly identical, but having only one half of a pair is a liability for the shopkeeper, much like selling only left shoes would be to a cobbler's detriment. However, as opposed to Tweedledum and Tweedledee, who chafe against each other and thus seem better off existing in the regular and Looking-Glass worlds, respectively, these doubles are designed to be inseparable.

Despite the shopkeeper's entreaties, Alice purchases a single egg, thereby implicitly privileging one stereoisomeric double over the other. But that egg, which 'only got larger and larger, and more and more human', soon transforms such that it is no longer one unified egg, but rather something thing destined to end up in multiple parts, that is, as Alice says, 'HUMPTY DUMPTY himself'(p. 183). '*My* name means the shape I am', claims Humpty Dumpty, and indeed he is correct, for the orthographical structure of 'Humpty Dumpty' expresses his stereoisomeric character. Identical in spelling save one letter, the two parts of the egg's moniker, when oriented around the plane of the mirror, reveal themselves to be non-superimposable.

H-U-M-P-T-Y ¦ Y-T-P-M-U-**D**

↑

Mirror

Figure 6: Stereoisomeric Character of 'Humpty Dumpty'

Although Humpty Dumpy thinks his shape 'a handsome one', he is not meant to retain it, for, as Alice recalls, he is to have a 'great fall', after which 'All the King's horses and all the King's men / Couldn't put Humpty Dumpty in his place again' (p. 184). Here, Carroll appropriates Humpty Dumpty and the corresponding nursery rhyme to hypothesize that even seemingly singular persons and things eventually dissemble into stereoisomeric doubles. Considering Humpty Dumpty grew from one of a pair

27 'Just then flew down a monstrous crow, / As black as a tar-barrel; / Which frightened both the heroes so, / They quite forget their quarrel' (p. 160).

of stereoisomeric eggs, then even a stereoisomeric double has the potential to generate its own stereoisomers.

Just before going to pieces, Humpty Dumpty provides Alice with some advice on aging, and in the process, invokes another set of stereoisomeric doubles. In response to Alice's claim that 'one can't help growing older', Humpty Dumpty insists, '*One* can't, perhaps, but *two* can. With proper assistance you might have left off at seven' (p. 186; italics Carroll's). Alice subsequently interrupts Humpty Dumpty to admire his 'beautiful belt', because, she thought, 'they had had quite enough of the subject of age'. But Humpty Dumpty is far from finished with his lecture, and simply incorporates Alice's observation into his original line of argument about aging by telling her that the belt was a present for his 'unbirthday', which he defines as a 'day when it isn't your birthday' (p. 187). As the reverse of a regular birthday, the 'unbirthday' is very similar in structure to the birthday but by implication has one very important distinguishing property: the power to undo or reverse the effects of the regular birthday. Furthermore, Humpty Dumpty's previous assertion that *two* not *one* can halt the aging process suggests that birthdays and unbirthdays, unlike other stereoisomeric doubles, can in theory operate in harmony to produce some beneficial effect. But what is problematic and troubling about this conceptualization is that one stereoisomeric form (the unbirthday) exists in extreme disproportion to the other form (the birthday). The preponderance of unbirthdays means not that a person like Alice would be fixed at seven years, but that she would age backward until she no longer exists. As in the case of Tweedledum and Tweedledee, Carroll here imagines that when two stereoisomeric doubles occupy the same space they are inevitably pitted against each other in such a way as to cause one double to dominate the other. In this way, Carroll suggests a dual chemical world may be ultimately untenable and that some measure of segregation is necessary for stereoisomeric doubles to co-exist equally.

Stereoisomeric Doubling in the Regular World

The theory of stereoisomerism provided Lewis Carroll with a scientific foundation not only for the doubles in his work but also for those in his own life. Indeed, the idea of two-part self or 'double' identity would have held special significance for Lewis Carroll, or Charles Dodgson as he was better known to friends and family. The reverend and mathematician insisted on keeping these two identities distinct both to shield himself from unwanted publicity (he repeatedly writes of his aversion to talking to strangers about his books) and to maintain his professional integrity.28

28 Dodgson's fear that reviewers and academics who knew he wrote books for children might disregard his mathematical publications was not unfounded, for 'some reviews of his serious books fell into that superficial mode when the writers linked the two names' (Cohen, p. 298).

The fact that Dodgson so emphatically denied he had anything to do with Lewis Carroll has led many critics to pathologize his pseudonymity. Douglas Nickel notes that 'several authors, beginning with Langford Reed, saw in Dodgson's discomfort with Carroll evidence of a split personality'.29 Cohen acknowledges that 'others have seen [in Dodgson]…a bifurcation, a dual persona', but dismisses such an evaluation as 'a view easily disposed of'. The author's 'reasons for keeping his two identities separate and under control were rational and reasonable', counters Cohen, pointing out that maintaining a pseudonym was also important so that children would not be intimidated by Dodgson.30

But Dodgson's motivation to keep his two identities separate may have been based on science as well as reason. The great lengths to which he tried to isolate C.L. Dodgson from Lewis Carroll suggest he regarded them not only as separate but also, more importantly, non-overlapping entities. He did everything possible to establish author and mathematician as mutually exclusive, returning unopened letters received at Christ Church that were addressed to Lewis Carroll and referring to the author in third person in epistolary correspondence. One therefore wonders if and when Dodgson began to read about isomerism he found a chemical basis for thinking that one person could exist in two different chemical forms each with its own professional properties. Lewis Carroll and Charles Dodgson, the author may have been imagined, are human stereoisomers, structurally similar yet non-superimposable, each with his own professional attributes.

Stereoisomerism for Carroll thus provided a new scientific foundation for a much older idea: that any given person or thing could exist in two forms. By conceptualizing these two forms using theories of chemistry, Carroll innovated the motif of the double, changing it from a literary device to a means by which scientific fact could intervene in an otherwise fictional narrative. Stereoisomeric doubles therefore render the Looking-Glass world an alternative reality rather than an improbable fantasy. As specimens from this scientifically Other world, 'Unbirthdays', Humpty Dumpty, Tweedledum and Tweedledee, and Looking-Glass milk represent Carroll's intense contemplation on the complex implications of chemical duality. The diverse stereoisomeric doubles featured in *Through the Looking-Glass* complicate any assumptions that each set comprises a "good" and a "bad" form and instead suggests that each is suitable and appropriate in a certain space.

29 Douglas R. Nickel, *Dreaming in Pictures: The Photography of Lewis Carroll* (New Haven, CT: Yale University Press, 2002), p. 27.

30 'If [Dodgson's young friends] saw him as a famous man…they would grow shy and tongue-tied, and a natural friendship might never develop' (Cohen, p. 192).

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