Frederick Burwick

The Damnation of Newton

Quellen und Forschungen
zur Sprach- und Kulturgeschichte
der germanischen Völker

Begründet von
Bernhard Ten Brink und
Wilhelm Scherer

Neue Folge
Herausgegeben von
Stefan Sonderegger

86 (210)

Walter de Gruyter · Berlin · New York
1986

The Damnation of Newton: Goethe's Color Theory and Romantic Perception

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Walter de Gruyter · Berlin · New York
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Printed on acid free paper
(ageing-resistant – pH7, neutral)

Library of Congress Cataloging-in-Publication Data

Burwick, Frederick.
The damnation of Newton.

(Quellen und Forschungen zur Sprach- und Kulturgeschichte der germanischen Völker ; n. F. ; 86 (210))
Bibliography: p.
Includes index.
1. Goethe, Johann Wolfgang von, 1749–1832 – Zur Farbenlehre. 2. Goethe, Johann Wolfgang von, 1749–1832 – Knowledge – Science. 3. Goethe, Johann Wolfgang von, 1749–1832 – Aesthetics. 4. Color. 5. Visual perception. 6. German literature – 19th century – History and criticism. 7. Romanticism – Germany. 8. English literature – 19th century – History and criticism. 9. Romanticism – England. 10. Literature, Comparative – German and English. 11. Literature, Comparative – English and German. I. Title. II. Series: Quellen und Forschungen zur Sprach- und Kulturgeschichte der germanischen Völker ; n. F. 86.
PT2208.C7B87 1986 535.6'092'4 86-13455
ISBN 0-89925-207-9 (U.S. : alk. paper)

CIP-Kurztitelaufnahme der Deutschen Bibliothek

Burwick, Frederick:
The damnation of Newton: Goethe's color theory and romantic perception / by Frederick Burwick. – Berlin ; New York : de Gruyter, 1986.
(Quellen und Forschungen zur Sprach- und Kulturgeschichte der germanischen Völker ; N. F., 86 = 210)
ISBN 3-11-010765-1
NE: GT

ISSN 0481-3596

Satz und Druck: Saladruck, Berlin
Buchbindearbeiten: Lüderitz & Bauer, Berlin
Printed in Germany

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Prelude in the Academy

When "The Damnation of Faust" emerged in the folk tradition of the sixteenth century, the story was fraught with the concerns over the revolutionary changes taking place in society: alchemy and astrology were being replaced by chemistry and astronomy; religious dogma and ecclesiastical hierarchy were being altered by the forces of the Reformation and Counter-Reformation; feudalism was giving way to a mercantile bourgeoisie. The historical Dr. Faustus was a contemporary of Copernicus, Paracelsus, and Nostradamus; of Luther, Erasmus, and More; of Dürer and Hans Sachs. Goethe saw in the Faustian story certain conditions that had peculiar relevance to his own age of radical changes in science, religion and politics. The telescope of Herschel, the "pneumatic" chemistry of Lavoisier, the battery of Volta were among the recent advances which particularly excited Goethe's interests in science. Next to Shakespeare and Spinoza, Linné had "die größte Wirkung" on his thinking and prompted his study of botany ("Geschichte meines botanischen Studiums," 1817). In religion, the profound influence of the Deists stirred his endeavor to redefine theodicy. In politics, Robespierre's "Reign of Terror" and Napoleon's lust for empire taught a conservative restraint to the author of *Götz von Berlichingen.*

In 1798, Goethe wrote the prelude in the theater as the second of the three prologues to his *Faust.* The spirit of the age is addressed by the theater director, the playwright, and a merry member of the audience. Commercial interests are pitted against aesthetic ideals, and both must somehow satisfy the popular appetite for entertainment:

Laßt Phantasie mit allen ihren Chören
Vernunft, Verstand, Empfindung, Leidenschaft,
Doch merkt euch wohl! nicht ohne Narrheit hören! (ll. 86–88)

The prelude in the theater concludes with the director's command to bring the light of the sun and moon, the theatrical machinery of the cosmos, into the action of the stage:

Gebraucht das groß' und kleine Himmelslicht,
Die Sterne dürfet ihr verschwenden;
An Wasser, Feuer, Felsenwänden,
An Tier und Vögeln fehlt es nicht.
So schreitet in dem engen Bretterhaus

Den ganzen Kreis der Schöpfung aus
Und wandelt mit bedächt'ger Schnelle
Vom Himmel durch die Welt zur Hölle. (ll. 235–242)

The claim to open up the entire "Kreis der Schöpfung" may sound like grand theatrical presumption, but no less grand were Goethe's pretensions to create a true "Weltbühne" from the story of Faust, to transform the story into the drama of man's knowledge and passion.

The need for a "Vorspiel" and a "Prolog" to *Faust* arose from the expectations and preconceptions about the drama and the Faustian story which he felt might interfere with the reception of this work. Thus his "Vorspiel" attempted to describe the causal conditions, culminating in the audience response to the dramatic production, as beginning with a poetic idea which must gain preeminence over literary form and theatrical conventions. The "Prolog" borrowed from the story of Job to provide a new context for understanding the trial of Faust. In presenting his *Farbenlehre*, he recognized an even greater need for a prelude and a prologue to mitigate the "Mißbilligung der bis jetzt herrschenden Theorie" (Polemik, § 1). Such was Goethe's purpose in writing not only the "Polemischer Theil," but also the "Historischer Theil," which was "auch schon... vielfach polemischer Art" (Eckermann, 15 May 1831). A third prologue, had Goethe been able to appraise the prevailing confusion of scientific *versus* philosophical approaches to the problems affecting the perception of light and color, might well have served his purpose more effectively than his polemics. In his history he set forth, clearly enough, the differing positions of Descartes, Huygens, Grimaldi, Boyle, and Newton, yet in summarizing the contributions of Malebranche, or of Voltaire, he drew no distinction between the epistemological and the scientific investigation of perception. A worthwhile prologue, a prelude in the academy, might have dealt with the issues of light and color as they had been debated not only by the physicists, but also by the physiologists, and the philosophers.

Although his very involvement in the natural sciences would seem to confirm his belief that scientific inquiries are directly relevant to aesthetic and epistemological issues, his own commitment to "gegenständliches Denken," which he documented as early as "Der Versuch als Vermittler zwischen Subjekt und Objekt" (1793), made him chary of the introspective or subjective direction in perception theory. According to prevailing terminology, physical optics were objective and physiological optics subjective. Not until the 1820's did Goethe learn, from Purkinje and Müller, that the subjective phenomena of retinal response could be objectively determined and scrutinized as "Gegenstände." Only late in his career did he admit the physiological ground of his *Farbenlehre.*

Berkeley and Hume had been so successful in separating the philosophical theory of sense perception from the empirical investigation, whether of physics or physiology, that Goethe was apparently willing to set it aside as a derivative, speculative, and essentially subjective mode of discourse. Nevertheless, in his attempt to explain the interaction of the subjective and objective in the act of seeing, he resorted to questions about the nature of perception similar to those discussed in Malebranche's *De la recherche de la vérité* (1674), Berkeley's *An Essay toward a new Theory of Vision* (1709), Condillac's *Traité des sensations* (1754), or Reid's *Inquiry into the Human Mind* (1764). The disparate presumptions of the physicist, physiologist, and philosopher were never brought into the *Farbenlehre* with that concert of purpose that unified the "Direktor, Theaterdichter, und Lustige Person" in the "Vorspiel auf dem Theater."

The age of Faust had been the age of "Renaissance man," a time when the possibility of universal knowledge, mastery of the arts and sciences, still seemed to be open to the ambitious mind. Whether the awful separation and dispersion of intellectual endeavors, dubbed the "two cultures" by C. P. Snow, should be dated as a phenomenon of the Romantic age, might not seem likely. After all, Thomas Young, Humphry Davy, William Rowan Hamilton could all make serious claims to humanistic breadth, if not universality, in their intellectual accomplishments. Nevertheless, a rift between the arts and the sciences was evident, and a need was recognized to reconcile the apparent antagonism. Such was the theme of Humphry Davy's "Parallels between Art and Science" (*The Director,* No. 19, 30 May 1807) and Johann Ritter's *Die Physik als Kunst* (1806). Thomas De Quincey believed that the antagonistic developments had accelerated with dangerous rapidity; in 1845 he reported his alarm:

> Already, in this year 1845, what by the procession through fifty years of mighty revolutions amongst the kingdoms of the earth, what by the continual development of vast physical agencies – steam in all its applications, light getting under harness as a slave for man, powers from heaven descending upon education and accelerations of the press, powers from hell (as it might seem, but these also celestial) coming round upon artillery and the forces of destruction – the eye of the calmest observer is troubled; the brain is haunted as if by some jealousy of ghostly beings moving amongst us; and it becomes too evident that, unless this colossal pace of advance can be retarded (a thing not to be expected), or, which is happily more probable, can be met by counter-forces of corresponding magnitude – forces in the direction of religion or profound philosophy that shall radiate centrifugally against this storm of life so perilously centripetal towards the vortex of the merely human – left to itself, the natural tendency of so chaotic a tumult must be to evil (*Blackwood's Magazine,* March 1845).

Granting the impossibility of slowing down scientific progress, De Quincey urged an increased attention to religion and philosophy in order to restore the balance between the objective and the subjective, between the physical world and the introspective realm of consciousness.

At the very beginning of the fifty-year period surveyed by De Quincey, Goethe had convinced himself that a mediation, at least, was possible, and that the power of his mind was equal to whatever task of inquiry he might undertake. His success was not meagre. His contribution to science, more than his literary works, he confidently assured Eckermann (19 February 1829), would secure his place in history. Especially "in der schwierigen Wissenschaft der Farbenlehre," he was certain that he alone had offered the true explanation. Yet among all of his scientific endeavors, it was the color theory that aroused the most adamant opposition. For his contributions to plant morphology, Goethe's pretensions would seem justified. Indeed, the very term "Morphologie" was coined by Goethe; both phyllotaxy and classical flower theory were indebted to Goethe's observations on the "Spiraltendenz." In opposing Linné's system, John Lindley argued that "physiological characters are of greater importance than structural in regulating the natural classification of plants," and he acknowledged that "above all things, the adoption of the philosophical views of Goethe, together with the recognition of an universal unity of design," had been responsible for the progress in botanical science ("On the principal question at present debated in the Philosophy of Botany," *Reports of the British Association for the Advancement of Science*, Cambridge, 1833). In his *History of the Inductive Sciences* (1837), William Whewell gives prominence to "Goethe's views on the laws which connect the forms of plants into one simple system," and adds that "the same remarkable man, who... gave so great an impulse to vegetable morphology" also forwarded the study of animal morphology in his essay on the intermaxillary bone and his studies in comparative anatomy. Although he thus extolled Goethe's work in biology, he was more modest in appraising the studies in mineralogy; as for the *Farbenlehre*, he could only lament that Goethe had allowed "poetic imagination" to take the place of disciplined "geometrical thought" (quoted in Erwin B. Wolff, "On Goethe's Reputation as a Scientist in Nineteenth-Century England," *German Life and Letters*, VI [1962–63], 92–102).

Achim von Arnim gave a similar appraisal of Goethe's scientific endeavor in his review of *Dichtung und Wahrheit:*

> Die Mineralogen weigern sich nicht, ihn anzuerkennen, sie fühlen bey seinen Studien die Ergebung in den allgemeinen Zusammenhang des Gedachten, welche das wissenschaftliche Studium bezeichnet. Die Anatomen haben einigen Widerspruch, sie meinen Einzelheiten mehr als billig hervorgehoben, die zu nichts führen. Die Botaniker sind

> schon verdrießlich, sie meynen, daß das Wort, die Metamorphose nichts gebe, es ließen sich vielleicht noch ein Paar andere erfinden, die bedeutungsreicher wären. Ganz ärgerlich sind aber die Physiker durch den heftigen Streit gegen Neuton, der sogar des absichtlichen Betruges in der Farbenlehre geziehen wird (*Literatur-Blatt*, Nr. 66, 16 August 1822, 262).

"Der heftige Streit gegen Neuton" which Goethe conducted in the "Polemik" of his *Farbenlehre* was prompted in large part by his inability to understand the methods of physical optics. For all his effort to reassert the humanistic foundation and become the "Renaissance man" of his time, Goethe suffered one grand prejudice that is evident throughout his scientific studies: he rejected mathematics. Although he could pursue his biological studies without mathematics, his access to physics, more than he ever realized, was effectively blocked by his unwillingness to accept mathematical reasoning. Rudolf Steiner, in his edition of Goethe's *Naturwissenschaftliche Schriften* (1883–1897), maintained that Goethe was right to deny the charge that he had been "ein Widersacher, ein Feind der Mathematik": he had merely insisted that the qualitative must precede the quantitative study of nature. The fact remains, however, that Goethe persistently neglected the quantitative. In his "Über Mathematik und deren Mißbrauch" (1826), he argued "daß gewisse einzelne Fächer von Zeit zu Zeit ein Übergewicht in der Wissenschaft nehmen," and that his own age had witnessed a "Vorliebe für die Anwendung von Formeln" prevail to the point that it had become the end rather than the means; the reliance on algebra, geometry, and the calculus not only rendered the report of scientific research beyond the comprehension of the intelligent layman, it resulted in mathematical demonstration usurping the place of natural observation and experiment.

Goethe presented the "Didaktischer Theil" of his *Farbenlehre* as a counter-measure to the mathematical and mechanistic approach to optics. In the "Historischer Theil" he traced the course of the usurpation. And in the "Polemischer Theil" he enacted his "Damnation of Newton" by repeating the experiments of the *Opticks*. In my study of Goethe's color theory I have turned frequently to the commentaries by Rupprecht Matthaei. Although I cite the Weimar edition (1887–1919) of Goethe's works, I have consulted the Hamburg edition (5th ed., 1966) for the notes and commentary provided by C. F. von Weizsäcker and Dorothea Kuhn. For her attention to my account of the physiology and the psychology of seeing, and especially for her gently sceptical queries about my demonstration of Edwin Land's two-color projection phenomena, I am grateful to Dorothea Kuhn, who heard preliminary versions of the first three chapters. In these chapters, I describe how

Goethe's conception of the "Newtonian tyranny" informed the structure and the argument of the *Farbenlehre,* why he refused to recognize the physiological basis of his theory, and what use he made of the *Farbenlehre* in writing *Faust.* I then turn to Novalis and Achim von Armin, to Wordsworth, Coleridge, and Shelley, to explore further the concern with Newton's *Opticks* and the problem of perception. Like Goethe, these were poets attentive to the scientific developments of their day, and concerned about the widening rift between the arts and science.

The notebooks he kept during his studies at Freiberg, and later, reveal that Novalis had a keen and wide-ranging knowledge of science. I found a useful approach to the relationship between Novalis' scientific studies and his literary endeavor in John Neubauer's *Bifocal Vision, Novalis' Philosophy of Nature and Disease* (1971). In spite of a possible metaphorical implication of the title, *Bifocal Vision* does not address the problems of optics or perception. Nor does it look into Novalis' *Heinrich von Ofterdingen.* Fortunately, the work of Walter Wetzels was helpful to me on both counts: his *Johann Wilhelm Ritter: Physik im Wirkungsfeld der deutschen Romantik* (1973) guided me in defining the scientific context at large and Ritter's influence in particular; his "Klingsohrs Märchen als Science Fiction" (1973) impressed me as being so valid in its analysis that I felt it deserved more thorough application. Although Walter Wetzels has heard me present much of the material in my first two chapters, this chapter on Novalis will be something of a surprise to him.

My introduction to Achim von Arnim I owe to Roswitha Burwick. Her compilation, "Exzerpte Achim von Arnims zu unveröffentlichten Briefen" (1978), made me aware of Arnim's on-going interest in science. Through her skill in transcribing Arnim's handwriting, I have been able to draw from the large collection of unpublished manuscripts which date from the period of Arnim's research in electricity, magnetism, and physiological response. To Dr. Karl-Heinz Hahn, Director of the Goethe-Schiller-Archiv, Weimar, I owe my thanks for his permission to use the manuscripts of Arnim's "Studien zur Naturwissenschaft" (GSA 213).

The chapter on Wordsworth has undergone a series of transformations. When I participated in a program on Wordsworth with Geoffrey Durrant, we soon recognized that we radically differed in our understanding of what Wordsworth meant when he declared that the poet "will be ready to follow the steps of the Man of science." In its early form, this chapter was intended primarily as an answer to Durrant's *Wordsworth and the Great System* (1970). Thomas MacFarland generously praised and encouraged my effort, but persuaded me that I should not ignore *The Recluse.* If I have been able (indeed, even if I have not) to explain something more about the problems that confronted Wordsworth in trying to write *The Recluse,* I must acknowledge a debt to Thomas MacFarland and to his *Romanticism and the Forms of Ruin* (1981). For his chapter on "Coleridge's Doctrine of Polarity and Its European Contexts," and for our discussions on Schelling, I could have added many footnotes to other chapters.

In his critique of the early draft of the chapter on Coleridge and Jean Paul, Ernst Behler complained that I had confused science and pseudoscience. Without realizing it, he had identified a problem not simply in this chapter, but in the entire book. His criticism prompted a thorough re-writing, which has probably helped more elsewhere than here. Trevore Levere's *Poetry Realized in Nature, Samuel Taylor Coleridge and Early Nineteenth-Century Sciences* (1981) has been indispensable. Both this chapter and the next concern the problem of perception with particular attention to the appropriation of metaphor. The metaphorical language of Jean Paul, even more than of Coleridge, tends to be an alchemist's brew concocted with many pseudo-scientific potions but with enough distilled from science to make the mixture volatile. I have tried to be alert to both. The particular task of exploring Jean Paul was to document the complex intertextuality of Coleridge's notebook poems, "Limbo" and "Ne Plus Ultra."

For the analysis of animal magnetism in Schlegel, I am thoroughly indebted to Ursula Behler's edition of the *Tagebuch, Über die magnetische Behandlung der Gräfin Leśniowska, 1820–1826* (1979). Until the subsequent volumes of George Whalley's edition of Coleridge's *Marginalia* (*Collected Works,* 12; 1980) are available, transcriptions will probably continue to circulate like pirated video-tapes. For Coleridge's annotations to Kluge and Wolfart, however, I have consulted, first-hand, the volumes in the British Museum.

Carl Grabo, in *A Newton Among Poets, Shelley's Use of Science in Prometheus Unbound* (1930), did not present, in spite of the title, Shelley as a devoted adherent to the Newtonian tradition, for he draws evidence from both the undular and corpuscular theories without acknowledging any source of controversy. In citing Thomas Young's Bakerian lecture on interference, for example, Grabo merely observed: "Professor Young collects various passages from Newton's writings that relate to the luminiferous ether." Grabo gathered a valuable compendium of scientific allusion in Shelley's work, but he did not document the current debate on light and color. In this closing chapter, I supplement Grabo's work and also explain why Shelley claimed there were "traces" of *Faust* in his *Adonais.*

In *Newton Demands the Muse: Newton's Opticks and the Eighteenth-Century Poets* (1946), Marjorie Hope Nicholson concluded that with the close of the eighteenth century there was an end to the intimacy between science and art. As presage of the Romantic denunciation of science, she cited the poetry of William Blake. His aggressive anti-Newtonianism she finds, among other examples, in his annotation to the *Laocoon:* "Art is the Tree of Life. Science is the Tree of Death." In Nicholson's judgment, "William Blake presided at the poetic damnation of Sir Isaac Newton." Blake's opposition to "Newton's sleep," however, cannot be aggrandized into a Romantic rejection of science. Blake, after all, had great company, scientists and poets alike, in the growing anti-Newtonian controversy. For Blake, and for most of the Romantics, the foe was materialism not scientific inquiry. Blake, it should be remembered, praised the wedding of art and science; the curse was in "Generalizing art and science till art & science is lost." "What is the Life of Man, but Art & Science?" he asks in the last book of *Jerusalem* (1804–1820). "Answer this to yourselves, & expel from among you those who pretend to despise the labours of Art & Science." Not science, but science divorced from art, from the "Mental Gifts" of intellect, is what Blake opposed. Donald Ault, in *Visionary Physics, Blake's Response to Newton* (1974), made this case very well. His book, however, is more useful to students of Blake than to those interested in discovering literary dimensions in the history of science. The problem is that Blake, in spite of his technical skill as engraver in manipulating startling visual effects, understood very little of the science of optics and apparently was not even aware of the exciting discoveries that were taking place during the first years of the nineteenth century – infra-red, ultra-violet, and the interference of light.

If there was a poet of the age who "presided at the poetic damnation of Sir Isaac Newton," that poet was Goethe. For Goethe, as for many of the Romantics, Newton came to be seen as nemesis rather than apotheosis of man's perceptive capacity. After the century of Newtonian authority drew to a close, the support for a wave-theory of light, such as had been argued by Christian Huygens (1678) and Leonhard Euler (1746), began to win adherents who brought forth persuasive new evidence against the Newtonian theory of light as the rectilinear emission of corpuscles. At the same time, the experiments with electricity and magnetism brought about awareness of profound sources of energy pervading the world of matter and influencing, perhaps even animating as life-principle, the responses of living creatures. Here was an arena of inquiry that provoked the excitement of the poets and brought about large changes in the aesthetics and poetics of perception.

I. Goethe's *Farbenlehre:* The Newtonian Controversy

The reception of Goethe's *Farbenlehre,* from the time of its first publication in 1810 down to the present, has been more influenced by his attack against Newton's *Opticks* (1704) than by any other factor in Goethe's exposition of his theory.[1] For this reason, commentary on the *Farbenlehre* has remained preoccupied with accounts, pro and con, of Goethe's presentation of Newton. Where this task has been undertaken by those sympathetic to Goethe's intellectual integrity, the appraisal has been embarrassed or defensive. The physicists have accused him of dilettante speculation. Literary critics and art historians, for the most part, have chosen to ignore his concern with visual process and to deal only with his ideas on "Sinnlich-sittliche Wirkung" and "Ästhetische Wirkung."[2] The apology for Goethe's errors, following Hermann von Helmholtz, has been sought in the inadequacies of his technical apparatus.[3] The *Farbenlehre,* as defended by Rudolf Steiner, represents Goethe's effort to explain sensory perception as the link between subjective quality and objective quantity; thus it provides a scientific epistemology bridging the Kantian abyss between phenomena and

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[1] Manfred Richter, "Das Schrifttum über Goethes *Farbenlehre*" (diss., Dresden, 1936), in which the author attends to 458 publications, pro and con, on the color theory; G. Schmid, *Goethe und die Naturwissenschaft. Eine Bibliographie* (Halle, 1940); C. Gögelein, *Zu Goethes Begriff von Wissenschaft auf dem Wege seiner Farbstudien* (Munich: Hanser Verlag, 1972), includes a useful working bibliography.

[2] Although John Gage, in *Goethe on Art* (Berkeley and Los Angeles: University of California Press, 1980) exhibits both as translator and commentator a thorough command of Goethe's critical and aesthetic principles, his analysis of Goethe's *Theory of Colours* (Charles Eastlake's translation) in *Color in Turner* (New York: Praeger, 1969), apparently because he finds Turner's response thus constrained, neglects the account of visual processes, physical and physiological, and limits his discussion to the affective aspects. A similar limitation may be noted in Peter Schmidt, *Goethes Farbensymbolik, Untersuchungen zur Verwendung und Bedeutung der Farben in den Dichtungen und Schriften Goethes* (Berlin: Erich Schmidt Verlag, 1965); Schmidt declares that he does not intend a comprehensive study of the *Farbenlehre* but only of its literary relevance to Goethe's color symbolism.

[3] Hermann von Helmholtz, *Zwei Vorträge über Goethe,* ed. Walter König (Braunschweig, 1917); "Goethes naturwissenschaftliche Arbeiten" (1853), "Goethes Vorahnungen kommender naturwissenschaftlicher Ideen" (1892). The apology is in the latter lecture.

noumena.[4] Goethe's scientific redemption, as argued by Werner Heisenberg, must be derived from the differences between Newton's physical and Goethe's physiological premises.[5] Both the physiological and the epistemological approaches are useful in explaining the "Taten und Leiden" in Goethe's account of color perception. In order to explain his anti-Newtonian polemics, however, it is necessary to examine, as well, his argument on the strategic role of perception in both science and aesthetics.

Because his study of color theory extended over many years of his career, it is convenient to consider the chronology in terms of the specific problems which dominated his attention. Rupprecht Matthaei has grouped the work on color theory into four periods,[6] which I endorse, even though I have chosen to modify his divisions: the first period, 1791–1795, during which he produced the *Beiträge zur Optik,* (1791–1792); the second period, 1795–1810, during which he prepared his comprehensive *Farbenlehre;* the third period, 1810–1820, during which he conducted his experiments on entoptic phenomena; the fourth period, 1820–1832, during which he reviewed the work of Purkinje, elaborated the presentation of the physiological colors, and reorganized his supplementary studies as "Chromatik" rather than "Optik." I shall review the first two periods here and deal with the latter periods in the next chapter.

The first period, 1791–95, commenced with that experiment with the prism which he recollected in his "Confession des Verfassers" (1810). While traveling in Italy, 1786–1788, he had visited galleries and studios to look at the paintings, talk with the artists, and learn their techniques, "ihre tausendfältige Anwendungen und Ramifikationen." He found that one matter always eluded him: "es war das Kolorit." When it came to coloring, "so schien alles dem Zufall überlassen zu sein." He recalled his study of physics at the University of Leipzig under Professor J.H. Winkler, yet could not remember "die Experimente, wodurch die Newtonische Theorie bewiesen werden soll." He decided, therefore, to conduct such experiments for himself. He borrowed a prism from C.W.

[4] Rudolf Steiner, *Goethes naturwissenschaftliche Schriften* (Dornach: Rudolf Steiner Verlag, 1975, 3rd ed.). This edition, a reprint of the original edition in "Kürschners Deutsche National-Literatur" (1883–1897), also includes Steiner's subsequent notes and commentaries.

[5] Werner Heisenberg "Die Goethische und Newtonische Farbenlehre im Lichte der modernen Physik," *Geist der Zeit* (1941) XIX; reprinted in *Wandlungen in den Grundlagen der Naturwissenschaft* (Stuttgart 1959; 9th ed.), 85–106.

[6] Rupprecht Matthaei, *Goethes Farbenlehre,* (Ravensburg: Otto Maier Verlag, 1971), pp. 205–206.

Büttner. He prepared a room as a *camera obscura,* covering the one window with a sheet of metal which would allow sunlight to enter through a small hole of the prescribed dimensions. Before he could pursue the experiments, however, he moved. Then, too, Büttner wanted his prism back. In haste to complete the experiments, Goethe settled on a freshly painted room, with a wide-open window, in his new quarters. He took the prism and stared through it at the white walls and saw – the white walls, no colorful spectrum:

> Aber wie verwundert war ich, als die durch's Prisma angeschaute weiße Wand nach wie vor weiß blieb, daß nur da, wo ein Dunkles dran stieß, sich eine mehr oder weniger entschiedene Farbe zeigte, daß zuletzt die Fensterstäbe am allerlebhaftesten farbig erschienen, indessen am lichtgrauen Himmel draußen keine Spur von Färbung zu sehen war. Es bedurfte keiner langen Überlegung, so erkannte ich, daß eine Gränze notwendig sei, um Farben hervorzubringen, und ich sprach wie durch einen Instinkt sogleich vor mich laut aus, daß die Newtonische Lehre falsch sei.[7]

Of course what Goethe observed depended on conditions very different from those Newton had set forth in the *Opticks.* Goethe might not have realized the difference when he first performed the experiment early in 1791; in recollecting the event in 1810, however, he certainly was fully conscious of how radically his method departed from Newton's. When Newton first performed his experiment in 1666, he not only used the darkened chamber, he also placed the prism before the small hole which let in the light – not before his eyes. Newton's experiment was objective: he observed the beam of sunlight enter the prism and divide into rays that cast a colorful spectrum on the opposite wall; he deduced that the homogeneous light contained quantities of "diverse refrangibility" which produced an array from red, the least bent, through yellow, green, blue, to violet, the most bent. Goethe's experiment was subjective: with the prism before his eyes the light that was blocked by the narrow bar in the window appeared to radiate in bands of violet and blue on one side, red and yellow on the other side; he deduced that color arose on the surface or boundary because of the interaction or tension between light and darkness. It was not immediately evident to him that this interaction or tension might be a matter of retinal response, or that he was dealing with colors as qualities not quantities. Rather, he was convinced that he had discovered the fault of Newton's method: "Wenn sich dort das Licht in so vielerlei Farben auflös't, sagte ich zu mir selbst, so müßte ja hier auch die Finsterniß als in Farben aufgelös't angesehen

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[7] *Goethes Werke* (Weimar: Hermann Böhlau, 1887–1919), II. Abtheilung: Naturwissenschaftliche Schriften, Bd. 4, 295–296. References to this edition will be abbreviated WA in subsequent notes.

werden."[8] If Newton had not closed himself in a dark room and relied on such a small source of light, he would have been able to see the "Wechselwirkung" between light and darkness. With this conviction, Goethe published his *Beiträge zur Optik,* complete with a set of twenty-seven cards to be viewed through a prism so that readers might repeat the experiments and confirm for themselves the validity of Goethe's account.

In *Beiträge I,* he reiterated the root premise that informed *Die Metamorphose der Pflanzen* (1790): an *Urphänomen* is immanent in all process and change (§§ 5, 9). He described the appearance of the six elementary colors from the "Gesetz der farbigen Ränder" (§§ 8, 59), and posited the principle of polarity (§§ 50, 55). In *Beiträge, II,* he described how gray and colored surfaces appear to the eye through a prism. He also explained his use of the word "Strahlungen." Goethe's "Strahlungen" are subjective phenomena, not to be confused with Newton's "rays." Although in the first definition of the *Opticks* Newton stated that "By the Rays of Light I understand its least Parts, and those as well as Successive in the same Lines, as Contemporary in several Lines," it is not easy to determine whether he meant to identify the "ray" with the emission of a corpuscular mass, the "least Parts," whose size determine refrangibility, or with the "Lines" of their trajectory and their angles of refrangibility. The reference to "Parts" seems to relate "rays" to matter, while "Lines" would indicate their motion and direction. The rest of the definition stresses that the "ray" is something which can be materially isolated: "the least light or part of light, which may be stopped alone without the rest of the light, or propagated alone, or do or suffer any thing alone, which the rest of the light doth not or suffers not."[9] Goethe defined "Strahlungen" as the extension of the prismatic image: the colors which emerge along the black-and-white border, when viewed through the prism, may appear in sharply defined narrow bands at close range, but if viewed at an angle or at a distance the bands become broad and diffuse. Goethe's "Strahlungen" refer neither to the matter nor the motion of propagation, but only to the invisible phenomena.

During this early period, Goethe's analysis of color was limited to his experiments with the prism. While assembling material for a third volume of the *Beiträge,* he began to deal with visual phenomena, "die farbigen Schatten," which he could not readily bring into accord with his

[8] WA, II, Bd. 4, 297.

[9] Newton, *Opticks: Or, a Treatise on the Reflections. Refractions, Inflections and Colours of Light* (London: 1730, 4th ed.; reprinted by E. T. Whittaker, New York: G. Bell & Sons, 1931), Book I, Part I, Definition I, pp. 1–2.

previous interpretation. He consulted G. C. Lichtenberg, physics professor in Göttingen, who replied that the phenomena must be related to what Buffon had described in *Sur les coleurs accidentelles* (1743). Wrote Lichtenberg: "Es ist z. B. gewiß, daß wenn man lange durch ein rotes Glas sieht und zieht es plötzlich vor den Augen weg, so erscheinen die Gegenstände einen Augenblick grünlich."[10] Further work on the *Beiträge* ceased and the essay "Von den Farbigen Schatten" (1793) was put aside. Goethe turned his effort to the study of after-images and other physiological responses. His letter to S. T. Sömmering, anatomy professor in Kassel, reveals the shift in his research: "Es ist weit mehr Physiologisches bei den Farbenerscheinungen, als man denkt, nur ist hier die Schwierigkeit noch größer als in andern Fällen, das Objektive vom Subjektiven zu unterscheiden" (Jan./Feb., 1794).[11]

The second period (1795–1810) is marked by Goethe's concerted effort to prepare a comprehensive *Farbenlehre*. Returning to the problem that had provoked his earlier experiments with the prism, he began once more to study the optical effects attained by the artist's use of color: his introduction to the *Propyläen* (1798) and his review of "Diderots Versuch über die Malerei" (1791) were both directed toward that task later augmented by Heinrich Meyer's contributions, "Hypothetische Geschichte des Colorits" and "Geschichte des Colorits seit Wiederherstellung der Kunst," to the "Historischer Theil" of the *Farbenlehre*.[12] Goethe had confidence in the artist's gifted ability to observe and recreate the subtlest nuances in the perception of color. Unfortunately, the artist had neither a practical handbook nor even a theory which would explain the illusions of light and shadow in painting.[13] In the meantime, Goethe had also learned to his frustration that his *Beiträge* had failed to convert a single physicist from the Newtonian doctrine. Worse, it had stirred ridicule of his want of mathematics in attempting to account for phenomena of reflection and refraction. Such opposition prompted Goethe's polemical stance against Newtonian authority. He drafted a "Schema zur Geschichte der Farbenlehre" (10 Feb. 1799) in which he intended to reveal how the classical idea of color perception had been subverted by mathematical optics. As he now conceived it, a comprehensive theory must account for both the subjec-

[10] Quoted in Matthaei, *Goethes Farbenlehre*, p. 37.
[11] Quoted in Matthaei, *Goethes Farbenlehre*, p. 38.
[12] WA, II, Bd. 3, 68–107 and 353–381. See: Paul Weizsäcker, ed., *Kleine Schriften zur Kunst von Heinrich Meyer* (Heilbronn: Verlag Henninger, 1886), pp. xx–xlix; Wolfgang Pfeiffer-Belli, *Goethes Kunstmeyer und seine Welt* (Zurich: Artemis-Verlag, 1959).
[13] WA, II, Bd. 4, 288–292.

tive and objective phenomena in a manner which would resolve the disparities between the physiological and physical disciplines. Early in 1801, he visited with J. F. Blumenbach, professor of physiology in Göttingen.[14] During this time, too, Johann Ritter conducted with him a series of experiments on the effects of the prismatic spectrum on a plate coated with silver salts, and on the red and blue colors stimulated in the eye when touched by the positive and negative electrodes from the voltaic battery.[15] With Ritter, he studied William Herschel's discrimination of the "colorific" and "calorific" properties of light, which he appropriated as additional physical evidence of the predominance of light over darkness or darkness over light in the "farbige Strahlungen."[16] By summer, the "Schema der Farbenlehre" (2 Aug. 1801) was complete: although he would subsequently alter some of his terminology, he now recognized the advantage of the division into physiological, physical, and chemical colors. Five years later, he had repeated, with his own corrective variants, the experiments in Newton's *Opticks* and had outlined a history of color theory. His "Schema der ganzen Farbenlehre" (18 March 1806) presented the plan for his three-part work: the didactic (completed Feb. 1807), the polemic (completed Nov. 1808), and the history (completed Dec. 1809).

In his first definition, Newton wrote that the "part of Light, which may be stopped alone..., or propagated alone, or do or suffer any thing alone, ...I call a Ray of Light." For Goethe, light could neither be stopped nor isolated. When he repeated Newton's fifth experiment with the crossed prisms, he observed that Newton persisted in making this mistake, "daß er nämlich das prismatische Bild als ein fertiges, unveränderliches ansieht, da es doch eigentlich immer nur ein werdendes und immer abänderliches bleibt" (Polemik, § 10). It was Newton's delusion that light could "do or suffer anything alone": the doing and suffering must always be observed in terms of opposition, duality, polarity. Color is indeed the consequence of light doing and suffering, as Goethe readily affirmed in the preface to the "Didaktischer Theil": „Die Farben sind Taten des Lichts, Taten und Leiden." Yet he added immediately that the relation of light and color always depended upon a tension, a resistance:

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[14] Götz von Selle, *Universität Göttingen, Wesen und Geschichte* (Göttingen: Muster-Schmidt, 1953), pp. 68–69.

[15] "Galvanische Versuche bezüglich auf Phisiologische Farben," WA, II, Bd. 52, 201–202; Tagebuch (23 Feb. to 3 April 1801), WA, III, Bd. 3, 7–11.

[16] An Johann Wilhelm Ritter (7 March 1801), WA, IV, Bd. 15, 189–193; "Schreiben des Geh. Rath von Göthe an J. W. Ritter, Herschel's thermometrische Versuche in den Farben des Lichts betreffend; mit Anmerkungen von J. W. Ritter," in Gehlen's *Journal für die Chemie, Physik und Mineralogie,* VI (1808), 719–728.

"ein Mehr und Weniger, ein Wirken, ein Widerstreben, ein Tun, ein Leiden." Color may be "Taten des Lichts," but the action becomes visible only when light is pitted against darkness, when its energy works upon matter.

Visibility, of course, requires the beholding eye, but the eye itself is matter. The morphological idea prompted Goethe to consider the eye as a simple organic sensitivity to light which has gradually developed in some animals into more refined capacities of physiological response. In his fragmentary essay, "Das Auge" (1805/1806), he described the morphological evolution:

> Das Auge ist das letzte, höchste Resultat des Lichtes auf den organischen Körper. Das Auge als ein Geschöpf des Lichtes leistet alles, was das Licht selbst leisten kann. Das Licht überliefert das Sichtbare dem Auge; das Auge überliefert's dem ganzen Menschen.[17]

Not surprisingly, then, he began his theory with the "Physiologische Farben," asserting at the very outset, "Das Auge hat sein Dasein dem Licht zu danken." The eye is the organic consummation of the morphological process stimulated by light: "Aus gleichgültigen tierischen Hülfsorganen ruft sich das Licht ein Organ hervor, das seinesgleichen werde; und so bildet sich das Auge am Lichte fürs Licht, damit das innere Licht dem äußeren entgegentrete."[18]

Among the physiological colors Goethe distinguished the positive after-images, in which positive silhouette images are stimulated by bright light, and the negative after-images, in which intense colors are excited by staring at their contraries. Although Goethe referred simply to "fordernde" and "geforderte Farben," he accurately described successive contrast (§§ 48–55; 805–810), successive double contrast (§ 58), sustained and mixed contrast (§ 30), simultaneous contrast with grey on colored ground (§§ 56, 57; 690), simultaneous contrast with contrasting colors (§§ 57–61; 690; 805).[19] He then introduced the phenomena of "farbige Schatten" which he had been unable to assimilate into the *Beiträge.* He now accounted for the phenomena as "gefordert" in the same manner of retinal response as simultaneous contrast. He also provided an efficient experiment for producing colored shadows: two

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[17] WA, II, Bd. 52, 11–12.

[18] WA, II, Bd. 1, xxxi. See: Armin Tschermak-Seysenegg, "Goethes Farbenlehre und ihre Bedeutung für die physiologische Optik der Gegenwart," *Forschungen und Fortschritte,* VIII (1930); Rupprecht Matthaei, "Goethes biologische Farbenlehre," *Jahrbuch der Goethe-Gesellschaft,* I (n. s., 1936); Agnes Arber, *Sehen und Denken in der biologischen Forschung* (Hamburg, 1960).

[19] Johannes Pawlik, *Goethes Farbenlehre, Textauswahl mit einer Einführung und neuen Farbtafeln* (Cologne: DuMont, 1978).

candles (A and B) on each side of a white tabletop, a pane of colored glass ("fordernde Farbe") placed before one (A), a thin rod held between the two so that two shadows are cast: the shadow cast by candle (A) will have the "geforderte Farbe" and the shadow cast by candle (B) will have the "fordernde Farbe." With a red glass, for example, the candle will cast a green shadow. This experiment has been cited in recent years to explain Edwin Land's stunning demonstration of a colored photographic image cast by projecting two black-and-white slides and placing a color-filter ("fordernde Farbe") on the lens of one of the projectors.[20] Goethe also treated halos (around a candle flame, for example) as "subjektive Höfe" elicited by retinal response. He ought to have listed them, instead, among the diffraction patterns he discusses as the subjective-objective "Physische Farben."

By "Physische Farbe," Goethe meant those fugitive colors produced by the process of mediation. He gave them names which were not unusual in the literature of his day: dioptric 1 (§§ 143–177, dispersion: milk-glass looks red when held before the light, blue when held away from the light), dioptric 2 (§§ 178–365, refraction: the red-yellow and violet-blue bands which appear on each side of a black bar on a white background when viewed through a prism), katoptric (§§ 366–388, reflection: a silver plate held toward the sun will mirror bright light but no color; scratch the plate and an intense line of color will appear in the scratch and change as the angle of the plate is shifted), paroptic (§§ 389–428, diffraction: a thin wire held directly before the eye while looking at a candle flame will cause several bands of colors to appear at

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[20] Edwin Land, "Experiments in Color Vision," *Scientific American* (May, 1959), 84–99; Francis Bello, "An Astonishing New Theory of Color," *Fortune* (May, 1959), 144–48, 195–196, 200, 202, 205; "Die schlafende Schönheit," *Der Spiegel* (August, 1959) 57–60. See also: Edwin Land, "Color Vision and the Natural Image," *Proceedings of the National Academy of Sciences*, XLV, no. 1 (January, 1959), 115–129, and XLV, no. 4 (April, 1959), 636–644; M. H. Wilson and R. W. Brocklebank, "Two-color Projection Phenomena," *Journal of Photographic Science*, VIII (1960), 141 ff.; D. B. Judd, "Appraisal of Land's Work on Two primary Colour Projections," *Journal of the Optical Society of America*, L., no. 2 (February, 1960), 254 ff; John McCann and Jeanne Benton, "Interaction of the Long-Wave Cones and the Rods to Produce Color Sensations," *Journal of the Optical Society of America*, LIX, no. 1 (January, 1969), 103–107; Edwin Land and John McCann, "Lightness and Retinex Theory," *Journal of the Optical Society of America*, LXI, no. 1 (January, 1971), 1–11; Edwin Land, "The Retinex Theory of Color Vision," *Scientific American* (December, 1977), 108–130. On the relevance to Goethe: Heinrich Proskauer, *150 Jahre Goethes Farbenlehre und die Fruchtbarkeit ihrer Prinzipien zum Verständnis neuentdeckter Farbphänomene* (Dornach: Goethe-Farbenstudio, 1960); Gerhard Ott, „Die Versuche von Land. Ansätze zu ihrer goetheanistischen Deutung," in *Goethes Farbenlehre*, ed. H. Proskauer and G. Ott (Dornach: Verlag Freies Geistesleben, 1980), I, 283–289.

distances from both sides of the flame; concentric circles of color will appear inside of a small hole in a card held before the eye while looking toward the light), epoptic (§§ 429–485, interference: oil on water, soap bubbles, mica schist, etc.; the colors in thin glass plates change under pressure). To these "Physische Farben" Goethe later added the entoptic phenomena (polarization), which I describe in the next chapter.

The "Chemische Farben" are classed as objective because their color derives from the material substance or ground, but even these colors may vary with the varying light: the blue of distant mountains, for example, or the whiteness of sand along the seashore at mid-day that appears brown or gray towards sunset. Here Goethe also referred to mixing pigments, heating and cooling metals, and to the chemical alteration of color: bleaching, fading, tarnishing, rusting. He concludes with a survey of the colors of plants (greening of leaves, ripening of fruit) and animals (the irridescence of an insect, the shimmer of a bird feather, etc.).[21] By emphasizing the many factors which may change the "Chemische Farben" (§§ 494–612, "Ableitung," "Erregung," "Steigerung," "Kulmination," "Balancierung," "Umkehrung," "Mischung," "Mitteilung," "Entziehung"), he made it clear that the appearance even of the objective phenomena undergoes constant alteration and may be affected by a subtle shift of the light or movement of the eye. Even though the eye learns to perceive the constancy of color, it is also alert to the slightest variation.

In his exposition of these three categories of colors, physiological, physical, and chemical, Goethe formulated three laws: the law of polarity, the law of gradation, and the law of totality. After calling attention to their operation in the first three sections, he summed them up in the fourth ("Allgemeine Ansichten nach Innen," §§ 688–715). Since Newton had acknowledged and interpreted all of the phenomena Goethe described as "Physische Farben,"[22] the problems motivating the

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[21] Newton, *Opticks*, Book II, Part III, Proposition V: "The transparent parts of Bodies... reflect Rays of one Colour, and transmit those of another, on the same ground that thin Plates or Bubbles do reflect or transmit those Rays." Cf. Henrik Steffens, "Über die Bedeutung der Farbe in der Natur," in P. O. Runge, *Farbenkugel* (Hamburg, 1810), and F. S. Voigt, *Die Farben der organischen Körper* (Jena, 1816).

[22] Newton acknowledged three modes of propagation: reflection, refraction, and inflections; *Opticks*, Book I, Part I, analyzes the phenomena of reflection and refraction which Goethe labelled dioptric 2 and katoptric; Book I, Part II, experiments 4 and 12 deal with epoptic and paroptic phenomena; the epoptic are further examined in Book II, Part I ("Colors of thin transparent bodies"), the katoptric in Book II, Part IV ("the reflexions and colours of thick transparent polished plates"), and the paroptic in Book III, Part I ("the inflexions of the rays of light and the colours made thereby"). For a comparative study of the *Opticks* and *Farbenlehre*, see: Maurice Martin, *Die Kontroverse um die Farbenlehre* (Schaffhausen: Novalis Verlag, 1979).

Newtonian polemic obviously reside in Goethe's interpretation of their subjective-objective "Vermittlung." Goethe was concerned with mediation of perception, not with the propagation of light.[23] In recounting the three experiments reported by Newton in his letter to Henry Oldenburg, Royal Society (6 Feb. 1671 o. s.), Goethe complained that they were "höchst abgeleitet," obscuring rather than revealing the *Urphänomen.*[24] He repeated this distinction in his indictment of all scientific research when it becomes distracted into pursuing "ein abgeleitetes Phänomen" instead of "das Urphänomen" (Didaktik, § 176). Later he would identify the *Urphänomen* as coexistent with the *Phänomen* in the entoptic figure. In his discussion of dioptrics, however, the *Urphänomen* is said to reside in a shaded medium which he called "das trübe Mittel":

> Ein solches Urphänomen ist dasjenige, das wir bisher dargestellt haben. Wir sehen auf der einen Seite das Licht, das Helle, auf der andern die Finsterniß, das Dunkle, wir bringen die Trübe zwischen beide, und aus diesen Gegensätzen, mit Hülfe gedachter Vermittlung, entwickeln sich, gleichfalls in einem Gegensatz, die Farben, deuten aber alsbald, durch einen Wechselbezug, unmittelbar auf ein Gemeinsames wieder zurück (Didaktik, § 175).[25]

Nowhere else does he manage to give an example of "trübes Mittel" as clear and precise as the example he draws in the dioptrics (§§ 238–241). Seen through the angle of a prism, a white square on a black background appears both as a primary and an overlapping secondary image ("Haupt- und Nebenbild"). Where the two images overlap (at top and bottom if the prism is held horizontally), the "Nebenbild" seems to pull some of the top black border down into the white square of the "Hauptbild" and also to push its lower edge across the bottom black border. Where primary and secondary images of the white square overlap with each other there is no change in the whiteness; where they overlap with the black border they create that "trübes Mittel" in which the bands of color appear. At the top, the brighter primary image makes the black border lighter, creating the lighter red-yellow bands. At the bottom, within the darker secondary image, appear the darker blue-violet bands. Goethe derived the law of polarity from the opposition of light and darkness. The opposition and interaction of light and darkness generate a tension

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[23] In his critique of the "Physikalische Preisaufgabe der Petersburger Akademie der Wissenschaften" (1826), Goethe denied both the undular and the corpuscular theories of propagation; WA, II, Bd. 5, 427–436.

[24] „Historischer Theil," WA, II, Bd. 4, 47.

[25] WA, II, Bd. 1, 72–73; for further references to the *Urphänomen,* see: WA, II, Bd. 1, 287; Bd. 3, 236; Bd. 5, 348; Bd. 5^2, 70.

within the "trübes Mittel" which becomes visible as color. He recognized numerous attributes of the *plus* and *minus* activity of light and darkness: the red/yellow end of the spectrum participated more in the brightness, vitality, and warmth of light; the blue/violet end shared more of the shade, infirmity, and cold of darkness (§ 696).

In his attempt to account for the qualities of brightness, hue, and saturation, Goethe formulated the law of gradation. This law follows from the law of polarity: the transition from yellow to red, or from blue to violet, is attributed to the degrees of tension in the polar opposition. The polarity of yellow and blue, under increased intensity, becomes the "gesteigerte Polarität" of red and violet. In the "Chemische Farben," Goethe provided a simple demonstration of intensity or augmentation in support of his law of gradation. A translucent white porcelain container, shaped in stair-steps, is filled with a yellow liquid; the top step is light yellow but the succeeding steps shade into orange approaching red. A second stair-step container is filled with a blue liquid; the steps are colored in gradations from light blue to violet (§§ 518–519).[26] "Die Steigerung," he explained, "erscheint uns als eine In-sich-selbst-Drängung, Sättigung, Beschattung der Farben" (§ 517). In the "Physische Farben," the "Strahlungen" in the "trübes Mittel" exhibit degrees of intensity. In the "Physiologische Farben," the intensity of an after-image is not only gauged by the factors inherent in the primary stimulus, but also by duration.

The law of totality also follows the law of polarity, for it is exhibited in forces of complementation and reconciliation which accompany opposition and tension. Goethe drew evidence of this law most effectively from the "Physiologische Farben." The activity of the retinal response, in producing negative and positive after-images and in perceiving the "farbige Schatten," always exhibits the process of complementation. Goethe arranged the color-wheel with the complementary colors at opposite sides. The "fordernde" and "geforderte" colors reconcile the opposition and close the circle.[27] "Das Auge verlangt dabei ganz eigentlich Totalität und schließt in sich den Farbenkreis ab" (§ 60). In the aesthetics of color response, the physiological urge toward complementation and totality gives rise to "die Lehre von der Harmonie der Farben" (§ 61).

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[26] Matthaei, *Goethes Farbenlehre,* p. 141, has excellent color photographs of a modified version of Goethe's demonstration (§§ 518–519).

[27] Goethe compared the "Totalität" of the "fordernde" and "geforderte" physiological colors to the colors stimulated in Ritter's galvanic experiments, WA, II, Bd. 5^2, 191, 201–202. Matthaei, "Complementäre Farben. Zur Geschichte und Kritik eines Begriffes," *Neue Hefte zur Morphologie, IV (1962).*

In conducting the experiments in Newton's *Opticks,* Goethe made use of these same laws, laws which derived from subjective response. As is evident in his account of the "trübes Mittel," Goethe readily accepted Newton's argument on the "refrangibility" of light and he would have been content with the formulation that colors are produced by "refrangible rays," if only Newton would have acknowledged the necessary "Taten und Leiden" (Polemik, §§ 20–21). What he objected to so vigorously in the *Polemischer Theil* was Newton's apparent equation of the colors with the "diversely refrangible rays" contained in white light. Because his title addressed the "Colours of Light," because he specifically referred to the "Colours of Homogeneal Lights," and declared that the "Heterogeneal and Compound Lights" are "always compounded of the colours of Homogeneal Lights" (Book I, Part I, Definition VIII), Goethe assumed that Newton was talking about color as perceptual quality. Indeed, even the word "Optik," Goethe insisted, "handelt ausschließlich von Farbe, von farbigen Erscheinungen" (Polemik, § 9).[28] Newton, of course, meant to refer only to the rays of light. In his "Polemischer Theil," Goethe did not annotate Books II and III of the *Opticks;* he did, however, provide a thorough commentary on Book I, for he was principally concerned with repudiating the notion that color was contained in light.

In Proposition I, Newton stated: "Lights which differ in Colour, differ also in Degrees of Refrangibility." Goethe dismantled this statement literally word for word. The plural form of the first word was already a source of annoyance: "Lichter, mehrere Lichter! und was denn für Lichter?" Newton offered two experiments, subjective and objective, to support this proposition. Goethe objected: neither viewing the red and blue squares through a prism, nor projecting their images through a lens justified a claim to "Lights which differ in Colour" (§§ 25–81). Many pages later, Newton added the clarification:

> ... if at any time I speak of Light and Rays as coloured or endued with Colours, I would be understood to speak not philosophically and properly, but grossly, and accordingly to such Conceptions as vulgar People in seeing all these Experiments would be apt to frame. For the Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour (Book I, Part II, Prop. II, Definition).

[28] Goethe later claimed that the word "Optik" referred so exclusively to the mathematical discipline, that he would have been less misunderstood if he had named his *Beiträge* "Chromatik" rather than "Optik." He also recognized the physiological ground of his study: „Als ich zur Farbenlehre schritt, durfte ich mir nicht verläugnen, daß die Chromatik erst im Auge gegründet werden müsse," WA, II, Bd. 5^2, 388.

Goethe was not appeased. In thus distinguishing the physical quantity and the sensory quality, Newton was not interested in granting physiological capacities to interpret and evaluate the stimulus. He was merely trying to work out a compromise between his own corpuscular theory of light and Christian Huygens' wave theory. He disassociated light-rays from the perception of color in order to introduce the analogy of sound-waves and declare that light, too, was "a trembling Motion," a "Motion propagated from the Object," and that only when perceived "in the Sensorium" were "those Motions under the Forms of Colours." Goethe equated the corpuscular theory with philosophical Atomism and the wave theory with Dynamism.[29] He then accused Newton of a strategic ploy, "um jene theoretische Differenz aufzuheben und zu neutralisieren, das Atomistische der Newtonischen Vorstellungsart mit der dynamischen seiner Gegner zu amalgamieren, dergestalt, daß es wirklich aussehe, als sei zwischen beiden Lehren kein Unterschied" (§ 457). For others, the Newtonian controversy may have concerned the wave theory *versus* the corpuscular theory. For Goethe, it concerned not the propagation, but the perception of color. Even after Newton had prescinded the light-ray from color-sensation, he still attributed to the ray a "Power and Disposition to stir up a Sensation" which was mechanically determined, a matter of cause and effect. And Newton was absolutely certain of the effect:

> For all white, grey, red, yellow, green, blue, violet Bodies... in red homogeneal Light appeared totally red, in blue Light totally blue, in green Light totally green, and so of the other Colours. In the homogeneal Light of any Colour they all appeared totally of that same Colour, with this only Difference, that some of them reflected that Light more strongly, others more faintly. I never yet found any Body, which by reflecting homogeneal Light could sensibly change its Colour (Book I, Part II, Theorem II, Experiment 6).

Newton was wrong on both counts. The color constancy experiments of H. Helson, D. B. Judd, and V. B. Jeffers show that under chromatic "homogeneal Light," the eye is perfectly capable of adapting so that it can distinguish hue, lightness, and saturation; further, that the reflectance of an object does "sensibly change its Colour." Under Newton's "Rubrific or Red-making" rays, a gray paper on a white card will look blue-green, the same gray paper on a gray card will be recognized as

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[29] H. A. M. Snelders, Atomismus und Dynamismus im Zeitalter der deutschen romantischen Naturphilosophie," in ***Romantik in Deutschland,*** ed. Richard Brinkmann (Stuttgart: Metzler, 1978); see also: Jakob Friedrich Fries, "Atomistik und Dynamistik" (1807), in *Sämtliche Schriften* (Darmstadt: Scientia Verlag Aalen, 1975), XVII, 221–257.

colorless, and on a black card it will appear red.[30] Goethe ridiculed Newton's experiment as "etwas völlig Unwahres": "Der Versuch ist so einfach und läßt sich so leicht anstellen, daß die Falschheit dieser Angabe einem jeden leicht vor die Augen gebracht werden kann" (§ 446). Goethe also noted that surface and texture influenced judgment, therefore he proposed to conduct the experiment more efficiently "mit schönen farbigen, glatt auf Pappe gezogenen Papieren" (§ 453).

Newton explicitly denied that colors were caused by "new Modifications of the Light variously impress'd, according to the various Terminations of the Light and Shadow" (Book I, Part II, Prop. I, Theorem I). Since this was precisely what Goethe held to be true, he admitted that he had been especially curious how Newton would go about rendering "das Wahre unwahr" (§ 324). He blames Newton's procedures (the *camera obscura,* the small hole, and the extreme distances) for obscuring the phenomena. Goethe had already discredited Newton's *Experimentum crucis* (Book I, Part I, Prop. I, Experiment 6). Using a double *camera obscura* (with an opening in the back of the primary chamber to let the light pass into the secondary chamber), Newton arranged a prism in each chamber so that the second prism made the blue-violet band wider than the red-yellow band. Newton attributed the difference to "diverse refrangibility," evidence that the blue-violet rays had a sharper angle of refraction. Goethe answered that the distortion of the picture simply resulted from the angle of projection: "Hier ist also keine diverse Refrangibilität, es ist nur eine widerholte Refraktion, eine widerholte Verrückung, eine vermehrte Verlängerung, nichts mehr und nichts weniger" (§ 131). In his rebuttal to the *Experimentum crucis,* Goethe introduced cross-references to his subjective experiments (Didaktik, §§ 210, 324) in which he explained the circumstances influencing the extension or distortion of the "Farbenerscheinung."

The cross-references are important, for Goethe used them to shift from Newton's objective experiments to his own evidence on the "Physiologische" and "Physische Farben." Goethe countered Newton's experiments with some experiments of his own which produced rather

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[30] H. Helson, "Fundamental problems in color vision I. The principle governing changes in hue, saturation, and lightness of non-selective samples in chromatic illumination," *Journal of Experimental Psychology,* XXIII (1938), 439–476; Helson and V. B. Jeffers, "Fundamental problems in color vision II. Hue, brightness, and saturation of selective samples in chromatic illumination," *Journal of Experimental Psychology* XXVI (1940), 1–27; D. B. Judd, "Hue, saturation, and lightness of surface colors with chromatic illumination," *Journal of the Optical Society of America,* XXX (1940), 2–32. See also: Helson, *Adaptation-level Theory* (New York: Harper & Row, 1964); Jacob Beck, *Surface Color Perception* (Ithaca: Cornell University Press, 1972).

astonishing evidence on the physiological response to color. In those experiments in which Newton required two prisms, or a prism and a lens, Goethe maintained that the images were always independent. By transforming the objective experiment into a subjective one, simply by placing his own eye at the point where Newton projected an image, Goethe always identified the "prismatisches Bild" as red-yellow and blue-violet "Strahlungen" separated by white light. Where Newton had shown that a lens could reconstitute the spectrum into white light, Goethe saw through the lens both "das Licht" and "die Farbenerscheinung," just as he saw them both through the first prism. Where Newton noted that if the first prism was set up so that only the yellow band passed through, then the second prism could neither break the yellow light further into colors nor could the lens reconstitute white light, Goethe again placed his eye before the projected image and again discovered both "das Licht," pure and white, and "die Farbenerscheinung" in full array. Only recent research has confirmed that the eye may see the full array of color within a narrow band of the visible spectrum.[31] Relying on his own subjective experiment, Goethe never doubted that his eye would behold the colors. Nor did he believe in red-making or yellow-making rays. Whereas Newton had mistaken the prismatic image as "ein fertiges, unveränderliches," he correctly saw it, with his own eyes, as "immer nur ein werdendes, und immer abänderliches" (§ 101).

To one of Goethe's repeated assertions of his essential doctrine of polarity and autonomous response, "die Sonne sei bei objektiven prismatischen Experimenten nur als ein leuchtendes Bild zu betrachten" (§ 241), Rudolf Steiner anchored a footnote that is perhaps too heavily restrictive. After complaining that modern physics ignores "wirkliche Tatsachen" in its preoccupation with "fingierte Objekte," Steiner goes on to segregate the phenomena of perception ("Die Sonne ist uns im Prozesse des Sehens nur als Bild gegeben") from its physical source and causal propagation: "Wenn uns dann die Forschung weiterführt und uns die handgreiflichen Ursachen dieses Bildes klarlegt, so dürfen wir nicht vergessen, daß jeder gedankliche Aufbau doch zuletzt auf die einfache Sinnesempfindung zurückgeht." He added that Goethe was concerned only with "Sinnes*empfindung*, nicht um eine Veranlassung, die mit dieser dem Wesen nach nichts gemein hat." Perhaps Steiner did not

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[31] R. M. Boynton, W. Schafer, and M. E. Neun, "Hue-wavelength relation measured by color-naming method for three retinal locations," *Science*, CXLVI (1964), 666–668; R. J. W. Mansfield, "Visual Adaptation: Retinal transduction, brightness and sensitivity," *Vision Research*, XVI (1976), 679–690.

intend that his italicized emphasis should also separate the *Empfindung* from the *Sinne* and *Sinnesphysiologie*. Certainly it is separation enough to set "Empfindung" apart from the physical "Veranlassung" and, thus, effectively close the *Farbenlehre* within a hermeneutic circle: "Der Vorgang erstreckt sich also nur von einer Empfindung zur andern. Alles Hinausgehen aus diesem Kreise (als Lichtstrahlen, Lichtbündel etc.) ist ganz und gar den Tatsachen widersprechend."[32] When Goethe defined color as "Taten und Leiden des Lichtes," and declared that light called forth the eye as "seinesgleichen," he obviously did not intend to separate "Empfindung" from "Veranlassung." He was, however, aware of the hermeneutic circle of his experimentation, yet he defined it in significantly different terms. He presented at the beginning of his "Polemischer Theil" the paradox, "daß sich durch Erfahrung und Versuch eigentlich nichts beweisen läßt."

Whether or not Newton intended his dictum, "hypotheses non fingo," to apply to all scientific endeavor,[33] the opinion widely prevailed that hypotheses and theories intruded upon scientific inquiry and tended to distort the observation and evaluation of experiment. Goethe charged Newton, in spite of the disclaimer, with imposing his hypothesis of "diverse refrangibility" to the point of begging the question in the very formulation of his experiments. In his opening statement on "Beweis durch Experimente," Goethe asserted that it was impossible to avoid hypothesizing. One could observe phenomena, set up careful experiments, and derive an order of predictability between experiment and observation; conclusions and proofs are nevertheless imposed:

> man kann einen gewissen Kreis des Wissens darstellen, man kann seine Anschauungen zur Gewißheit und Vollständigkeit erheben, und das, dächte ich, wäre schon genug. Folgerungen hingegen zieht jeder für sich daraus; beweisen läßt sich nichts dadurch. ... Alles, was Meinungen über die Dinge sind, gehört dem Individuum an ... Im Wissen wie im Handeln entscheidet das Vorurtheil alles, und das Vorurtheil, wie sein Name wohl bezeichnet, ist ein Urtheil vor der Untersuchung (§ 30).

Goethe's paradox strategically assaulted prejudices of prevailing Newtonian authority, yet it implicated Goethe's own endeavor in prejudice as well. Such a science may be relative and limited, but it has autonomy and freedom. Contrary to Steiner's fine segregation of the "wirkliche Tatsachen" of sensation from the "fingierte Objekte" of science, for Goethe the "Kreis des Wissens" did indeed enclose mediation "im Prozesse des Sehens." The Newtonian system sought to explain light and color in

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[32] Steiner, *Goethes naturwissenschaftliche Schriften,* III, 417; note to § 241.

[33] Maurice Mandelbaum, *Philosophy, Science, and Sense Perception* (Baltimore: The Johns Hopkins Press, 1964), pp. 61–117.

terms of mechanical laws that were not only oblivious to human sensation, but effectively denied that human response had any import in the physical event. Thus, for example, Newton could attribute such inevitable and invariable "Power" to a "Rubrific" ray. For Goethe, this was another instance of the invasion of mechanical philosophy upon the province of human being. The very sensations were defined as causally determined by external laws.[34] Denied free will, consciousness was indeed trapped, in Gilbert Ryle's phrase, as a poor "ghost in the machine."[35] The Newtonian tyranny, then, was not simply a tyranny of the academy, it was a tyranny of the mind.

Toward the end of the nineteenth century, Sir George Gabriel Stokes in his *Lectures on Light* (Aberdeen, 1883) recollected the suppression of scientific inquiry that attended the almost fanatical allegiance to Newtonian theory. Stokes had modest praise for Goethe's observations. More importantly, he offered a forthright caveat on the "lessons" to be learned from the "corpuscular" theory:

> It shows that we are not to expect to evolve the system of nature out of the depths of our inner consciousness, but to follow the painstaking inductive method of studying the phenomena presented to us, and be content to learn new laws and properties of natural objects. It shows that we are not to be disheartened by some preliminary difficulties from giving a patient hearing to a hypothesis of fair promise, assuming of course that those difficulties are not of the nature of contradictions between the results of observation or experiment, and conclusions certainly deducible from the hypothesis on trial. It shows that we are not to attach too great importance to great names, but to investigate in an unbiased manner the facts which lie open to our examination.[36]

Because of his own work in wave theory on double refraction and the dynamics of polarized light, Stokes could be expected to regard with favor Goethe's collaboration with Thomas Seebeck in the account of entoptic or polarized phenomena. I quote Stokes, however, not for his defense of Goethe, but for his returning to the Newtonians the very charge they had made against the early "heretics," namely that they had tried "to evolve the system of nature out of the depths of... inner conscious" that their method was introspective rather than inductive. Johann Christian Poggendorff, whose work in thermo-electrics was,

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[34] Arthur Zajonc, "Goethe's Theory of Color and Scientific Intuition," *American Journal of Physics,* XLIV (1976), 327–333, raises the question whether it might "be possible to develop the capacity to 'perceive' a physical law," and thereby overcome the division between the physical object and the physiological/psychological response: "The very process of attentive perception transform the observer in harmony with the perception."

[35] Gilbert Ryle, *The Concept of the Mind* (New York: Barnes & Noble, 1949).

[36] Quoted in Thomas Preston, *The Theory of Light,* ed. Alfred Porter (London: Macmillan, 5th ed. 1928), p. 20.

incidentally, also indebted to Thomas Seebeck, objected even more vehemently to the Newtonian tyranny. Poggendorff drew his historical perspective from his fifty years as editor of the *Annalen der Physik und Chemie*. On the repression of the wave theory he asserted "that there is no other instance in the history of modern physics in which the truth was so long kept down by authority."[37]

At the beginning of the century, however, there were few who dared to speak out against the Newtonian authority. For the anti-Newtonian argument of his *Dissertation on the Universe* (London, 1795), Richard Saumarez gained a reputation as a renegade from scientific orthodoxy which hazarded his position as surgeon at Magdalen Hospital. Not until he was secure in his private practice did Saumarez publish a full attack on the Newtonian system. In *Principles of Physiological and Physical Science* (1812), he argued the primacy of physiology and the human sensory system in determining and directing all possible questions in physics. Coleridge, long convinced that the Newtonian propositions on light were "monstrous FICTIONS!," was eager to meet this bold author, "who has just written a Book, a biggish one, to overthrow Sir Iky's System of Gravitation, Color, & the whole 39 Articles of the Hydrostatic, chemic, & Physiologic Churches" (17 July 1812).[38] The attack included the "Physiologic Churches" because of Saumarez's criticism of the instruction at Cambridge and Oxford, and the reform that he also proposed in *A New System of Physiology* (1798).[39]

Saumarez was not alone in seeking to redress the want of physiological relevance in Newtonian physics. J.J. Engel, a "Popularphilosoph" dedicated to teaching the bourgeoisie, yet with expertise neither in physics nor in physiology, claimed he would resolve on physiological grounds the "Streit zwischen den Anhängern Neutons und Eulers." In his *Versuch über das Licht* (1800), Engel identified the crux of Euler's objections to reside in the problem of the impenetrability of matter. If rays of "corpuscles," even the most minute, were supposed to be

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[37] Preston, p. 25. See also: Poggendorff, *Handwörterbuch zur Geschichte der exacten Wissenschaften*, I (Leipzig: Barth, 1863), ii.

[38] To John Rickman, 17 July 1812, *Collected Letters of Samuel Taylor Coleridge*, ed. Earl Leslie Griggs (Oxford: Clarendon Press, 1959), III, 414. Richard Saumarez, *A Dissertation on the Universe in general and on the Procession of the Elements in particular* (London, 1795); "Observations of the Generation and the Principles of Life," *London Medical and Physical Journal*, II (1799), 242, 321; *The Principles of Physiological and Physical Science; Comprehending the Ends for which Animated Beings were Created; and Examination of the unnatural and artificial Systems of Philosophy which now Prevail* (London, 1812).

[39] Saumarez, *A New System of Physiology*, 2 vols. (London, 1798; 2nd ed. 1799; 3rd ed. 1813).