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Defining the questions of the Farbenlehre

> Should I not be proud, when for twenty years I have had to admit to myself that the great Newton and all the mathematicians and noble calculators along with him were involved in a decisive error with respect to the doctrine of color, and that I among millions was the only one who knew what was right in this great subject of nature? With this feeling of superiority, then, it was possible for me to endure the stupid presumption of my opponents. They sought in every way to persecute me and my doctrine and to make my ideas ridiculous; but I nonetheless took great pleasure in my completed work. All the attacks of my opponents only served to help me see human beings in their weakness.
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> – Goethe (Eck., 30 December 1823)

The critical dilemma

The name Johann Wolfgang von Goethe (1749–1832) evokes the image of a giant of world literature. Although the epoch of adulation is past, and although his association with the bourgeois and petty aristocratic cultures of late eighteenth- and early nineteenth-century Germany has impaired his reputation, his greatness as a writer and his central role in the history of German literature are indisputable. Already in his youth he took the world of German letters by storm with his lyric poems, his drama *Götz von Berlichingen*, and his novel *Die Leiden des jungen Werther* – achievements that would have assured him an important chapter in literary histories. But it is the works of his maturity that truly guaranteed him human immortality as a writer and sage. Goethe's *Faust* is the most famous and greatest version of a story that has been taken as archetypal of the Western spirit. When we consider in addition novels like *Die Wahlverwandtschaften* and the two parts of the *Wilhelm Meister* saga, his autobiography *Dichtung und Wahrheit*, the *Italienische Reise*, the *West-östlicher Divan*, and countless other poems, stories, dramas, essays, translations, and letters, all written with masterly art and insight, we appreciate that, beyond whatever justice there is in comparing him

with Shakespeare and Dante, the sheer variety and richness of his literary production make him a writer sui generis.

Goethe was also active as a painter, a scholar, and a theater director and manager. He served as a director of universities and museums; an administrator responsible for parks, forests, mines, and roads; and a diplomat and minister of state. He was a scientist and patron of science and technology, with notable publications in anatomy, botany, and chromatics. Through this partial list of Goethe's activities and accomplishments, we begin to appreciate that this man was a German, or rather European, phenomenon with hardly a parallel. It is not at all surprising that to the civilization of ninteenth-century Europe he represented a pinnacle of human achievement. He was described already in the last years of his life as the Olympian, the calm, perfectly self-possessed, all-comprehending spirit who was the true heir of the entire legacy of the West and the fulfillment of the ideal of universal culture. He seemed to incarnate the spirit of antiquity and of the Renaissance, yet also to be a modern man whose powers were ample enough to range from rococo delicacy to the turbulence of *Sturm und Drang* romanticism, from the stern demands of natural science to the forms, depths, and delights of lyric – all without losing his unique individuality or undermining the masterful authority of his fundamentally classic spirit.

Goethe appeared to have followed the stirrings of his spirit even in science, but precisely here the universality of his genius is at issue. For Goethe believed that his major contribution to the sciences of nature, indeed the most important of all his works, was his Farbenlehre, his doctrine of color; yet, at least according to conventional wisdom, the poet was fundamentally in error. He appears to have committed an incredible blunder at the outset of his physical studies of color by rejecting Isaac Newton's theory of white light and colors as demonstrably false. A few casual observations with a prism appear to have settled his opinion: Observing that a white wall viewed through the prism remains white, and that colors appear only where there are contrasts of dark and light, he concluded that the notion that white light is separated into the various colors that compose it was wrong. Yet the phenomena he observed were not unknown to Newton, and so it seems that his insight amounted to nothing more than a misunderstanding of the theory. Although not a few scientists, both friends and strangers, tried to put him right, in person and in print, Goethe nevertheless held fast to his belief and continued his studies outside the traditional framework of optics and color science. As a result, he developed a theory of color that had little to do with physics and mathematics and that included a sustained attack on one of the greatest scientific achievements ever, Newton's op-

tics. Thus Goethe's Farbenlehre seems at best a curiosity, at worst a willful perversion of the human faculties.[1]

An oddity already in its own day, Goethe's Farbenlehre has grown stranger and more in need of explanation and apology with the passage of time. Occasional defenders, some eminent scientists, have been able to show at best that the work is not entirely peripheral to the concerns of modern optics and color science (e.g., Jablonski 1930). A few historians of science have been willing to resurrect it for its insights into the premodern conception of color rather than for any intrinsic scientific merit (see Wasserman 1978 and Judd 1970). Despite the time and labor that Goethe lavished on it, the Farbenlehre seems not to be informed with any genuinely scientific spirit or fundamental achievement. After more than 175 years the judgment of the eminent French physicist Etienne Malus still seems to hold:

> [There is] a striking contrast between the precise and simple manner in which Newton retails his experiments and conclusions, and the inflated, vague, and ironic tone with which Goethe denies the best known facts and the most evident consequences. . . .
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> . . . He treats the Newtonians as though they were Cossacks, their opinions as though they were incredible idiocies. . . .
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> . . . It is astonishing to see Goethe employ such arguments in a work of physics, and it is to be only too often perceived that he is not in the state of mind appropriate to those who sincerely seek the truth. (Malus 1811, 213, 218–19)

Aggressive and even insulting remarks about Newton and his followers can indeed be found in the second, polemical part and in the third, historical part of *Zur Farbenlehre*. Goethe variously calls Newton's theory contrafactual, a fairy tale, hocus-pocus, and word-rubbish (*Wortkram*); he accuses Newton of sophistry, stubbornness, and shamelessness, even of self-deception bordering on dishonesty. For the followers of Newton he shows even less tolerance. He berates them for being captious and dishonest, uttering thoughtless idiocies, spending their time gluing, mending, patching, and embalming Newton's theory. He calls them incompetent and obscurantist, lazy, self-satisfied, merciless, and persecutorial; they are mere copyists of error who constantly repeat the words of the master, record only what is favorable to the theory, and proceed in opposition to nature, intelligence, and common sense (see *FL-P*, par. 45, 76, 205, 356, 360, 471, 472, 582, 584, 635; and *WA* II, 4: 40, 64, 82, 101, 105, 106, 165).

To Goethe's early critics, the fact of his errors and intemperance was beyond doubt. Pointing them out was of course important, but attempts to understand the reasons behind them were far more revealing. By his own confession, Goethe had misunderstood Newton's theory and did

not have enough training in mathematics to judge its true rigor. Because Goethe was interested primarily in the artistic, poetic, and psychological uses of color, he did not properly evaluate the physics of color. His very talent, his poetic gift, inclined him more to romanticism, speculative *Naturphilosophie*, and the overvaluation of mere appearances, than to theoretical science and objective reality. The critical literature that followed, especially after Goethe's death, sought to explain why Goethe had committed his grave error and why he persisted in it.

Although there are signs that in the 1830s the controversy between scientists and supporters of Goethe was still topical (see Dove 1853, 15–16; cf. Schmid 1940, 347–50), by mid-century the debate had turned into a question about Goethe rather than about science. A milestone in this change was Hermann von Helmholtz's 1853 lecture on Goethe's scientific works. According to Helmholtz the facts of the matter are clear. In the *Beiträge zur Optik* Goethe describes what is seen when one looks through a prism at white figures on a black ground; black figures on a white ground; and colored figures on black, white, and colored grounds. He depicts the perceived phenomena "circumstantially, rigorously true to nature, and vividly, puts them in an order that is pleasant to survey, and proves himself here, as everywhere in the realm of the factual, to be the great master of exposition" (Helmholtz 1971, 28). Goethe thinks that the perceived phenomena are sufficient to contradict Newton, especially his two observations that, when viewed through a prism, the central portion of a broad white figure on a dark background remains white, and a narrow black stripe on a white ground is completely dissolved into colors. According to Helmholtz, however, the assumption in Newton's theories that white light is composed of differently refrangible, different color-producing lights can explain these phenomena very well.

Helmholtz suggests that at first Goethe remembered too little of Newton's theory to come upon this physical explanation of the facts; however, Goethe's subsequent discussions of the theory make clear that he did come to understand it. Nevertheless, he continued to insist that the incorrectness and absurdity of Newton's theory ought to be evident to all who have eyes to see, but without once plainly indicating exactly how it was unsatisfactory. Helmholtz expresses his perplexity: "And I for one do not know how anyone, regardless of what his views about colors are, can deny that the theory in itself is fully consequent, that its assumptions, once granted, explain the facts treated completely and indeed simply" (ibid., 30). Helmholtz remarked how disturbing Goethe's idiosyncratic stubbornness about Newton's theory is to all who consider the German poet to have been a man of the rarest spiritual capacities. Yet this opposition, Goethe versus the physicists – in agreement about the facts but in violent contradiction about their meaning – Helmholtz considers to

be revealing of a far deeper opposition, one which must be sought in the differences of character and ability that distinguish the poet from the scientist.

The poet-artist thinks that ideas must be immediate rather than abstract, and just as a work of art must not be subjected to any rending analysis that destroys it, neither should nature be rent by torturing experiment and abstraction. White is a simple sensation, regardless of what the scientist does with his prism, and so white cannot possibly be composite. A beam of light forced through prisms and lenses and apertures in dark rooms is nature put on a rack. Helmholtz grants that a poet-artist may have a genius for scientific description, as Goethe proved in osteology and botany, but nevertheless the artistic sensibility tends toward murky and ill-defined concepts that are essentially useless in exact physical science. Goethe, the poet par excellence, was unable to grasp precisely that abstract concepts are necessary to all real science. Direct, sensuous observation cannot substitute for well-defined concepts worked out by the intellect. Lacking geometry and an exact, theoretically guided experimental technique, Goethe could not penetrate to the ultimate forces of nature that are the proper realm of physical science. The poet, in his enthusiasm, in his longing for the realm of spirit, fails to recognize the legitimate claims of the material world. The duty of the scientist, on the other hand, is to discover the mechanisms of matter behind the appearances. This pathway is quite different from the poet's; yet it is not entirely blind to the inspiration of genius, and ultimately physical research is justified by enlarging the culture of humankind through subordination of the mechanisms of matter to the purposes of the ethical spirit (ibid., 30–43).

Helmholtz's understanding of Goethe's scientific work thus rests on his theory of the dichotomy of poet and scientist. A characterological or typological trait of the poet prevents him from grasping the real essence of science. On the other hand, the scientist must, to some extent, be open to the demands of spirit, and science is fundamentally part of a grand ethical quest. Earlier critics of the Farbenlehre had almost invariably raised the point that poets and scientists have different concerns and talents, but it was Helmholtz who made this distinction programmatic for understanding not only Goethe but also the very nature of science. Goethe's apparent inability to grasp the essence of Newton's science reveals the chief differences between those who cultivate imagination and human truth and those who pursue objective truth in nature. For the next seventy-five years both scientists and scholars followed Helmholtz's lead in their criticism of the poet-scientist Goethe.

The essay suffers from a curious imbalance, however. Although Helmholtz unified the themes of the earlier criticism, he also minimized an

important concession that his predecessors had allowed: He concentrated on the physical aspects of the Farbenlehre to the exclusion of the physiological and the psychological–aesthetic portions. He unrelentingly insisted that Goethe's science was intrinsically unphysical or antiphysical, a fact made evident by Goethe's opposition to Newton. Goethe's assault on Newton seemed to betray an incomprehension of all modern science per se. His apparent incapacity to understand physical science demanded not a scientific inquiry into the subject of color but rather a psychological inquiry into the mind and soul of Goethe as individual and poet. Helmholtz praised Goethe's descriptive powers, but in an age when the successes of abstract theoretical and applied physics seemed limitless this was hardly calculated to inspire trust in Goethe's scientific abilities. By disallowing the Farbenlehre's claim to be a genuinely physical science, Helmholtz undermined essentially its claim to being scientific. Thus there could be no good reason to take seriously either the work itself or its implicit attempt to discover a theoretical unity of physiology, physics, chemistry, and the perception of and reaction to color.

At the turn of the century there occurred a partial rehabilitation of the Farbenlehre when physiologists investigating the processes of color perception, chiefly advocates of Ewald Hering's color research and theories, rediscovered Goethe's so-called physiological colors. They came to regard the Farbenlehre as a legitimate progenitor of the physiology of the color sense, and scholars and scientists began to examine the work for anticipations of modern discoveries (Jablonski 1930). Although they viewed the work as a beginning science – pointing to the relevant phenomena and, to a certain extent, anticipating several important theoretical concepts – rather than a full-fledged science, this renewed credibility won the Farbenlehre a larger audience among laymen and scientists. The philosophical implications of Goethe's science also attracted increased attention and research, and literary historians no longer needed to feel embarrassed about Goethe's putative gaffe, because now they could cite praise from eminent researchers. By the 1920s and early 1930s the Farbenlehre was stirring even greater interest in the aftermath of the birth of the new physics, an interest reflected in the influential 1941 lecture on the doctrines of Goethe and Newton in light of modern physics by Werner Heisenberg.

Heisenberg agreed with traditional critics that Goethe's "fight for a more 'living' science in the field of color theory" was over; "the decision on 'right' and 'wrong' in all questions of detail has long since been taken. Goethe's colour theory has in many ways borne fruit in art, physiology and aesthetics. But victory, and hence influence on the research of the following century, has been Newton's" (Heisenberg 1952, 60). Nevertheless, Heisenberg admired what Goethe had accomplished. A chance

observation had spurred Goethe to contradict Newton and begin an intensive investigation of the origins of color, which Goethe attributed to "the combination of light and dark" in what he called the "Urphenomenon" of color. "This concept brings together into a unified, orderly whole the many effects of colours in our world of the senses rather by way of a guiding idea, based not on reason but on experience" (ibid., 62). In the Newtonian scheme, on the other hand, the simplest phenomenon is of a completely different order, "the narrow monochromatic ray purified by complicated mechanisms from light of other colours and directions" (ibid.). This phenomenon enables us to measure and predict optical phenomena, and every color can be associated with a number. What is simple in Newton's system, the monochromatic ray, is a complex phenomenon according to Goethe, and the simplicity of white light that was so evident to Goethe is denied by Newton.

Although Goethe's complaint that Newtonian physics does not encounter nature may be well taken, "on the other hand, the physicist can legitimately reproach Goethe in that his theory cannot be regarded as scientific since it cannot lead to a real control of optical phenomena" (ibid., 63). His theory tries to link together phenomena that to the physicist's mind must be kept separate and does not observe a careful distinction between subjective and objective. "It is just the very unity of Goethe's theory which [the physicist] cannot accept" (ibid., 64). Heisenberg's preliminary sketch then concludes with a judgment that leads to a new question.

> It is clear to all who have worked more recently on Goethe's and Newton's theories, that nothing can be gained from an investigation of their separate rights and wrongs. It is true that a decision can be taken on all points of detail and that in the few instances, where a real contradiction exists, Newton's scientific method is superior to Goethe's intuitive power, but basically the two theories simply deal with different things. (Ibid.)

The rest of the lecture is devoted to defining the domains proper to Goethe's kind of color science and to Newton's. Heisenberg disagrees with those who find no mathematics in the Farbenlehre (he believes Goethe's contrasts and symmetries recall the modern mathematical theory of symmetry), questions the adequacy of the poet–scientist dichotomy, and emphasizes that to say Goethe deals with color subjectively but Newton objectively is to forget that modern physics itself has blurred the distinction between subject and object. Although Goethe blundered when he entered the realm of Newton's physics, the very dilemma of modern physics is that it deals with a shadowy underworld rather than with the world of direct experience, that it depends on human decision and intervention that forces this underworld to appear, and that it is subject to all the fundamental limitations of human understanding. Hei-

senberg therefore concludes that it is necessary to continue Goethe's struggle against the physical theory of color on an extended front. Science singles out from the manifold physical phenomena a finite and limited field. The most serious task facing science today is to find the appropriate sciences for the various fields and aspects of reality. "Dividing reality in this way into different aspects immediately resolves the contradictions between Goethe's and Newton's theories of colour. In the great structure of science, the two theories take up different positions" (ibid., 75).

Heisenberg's conclusions appear conciliatory but are not revolutionary: They do not rehabilitate Goethe's physical science but only his sense of the limitations of physical science. Heisenberg's argument is important not because it defends Goethe from the accusation of being unscientific – the physiologists had already done this decades earlier – but because an eminent representative of physics retreated from the Helmholtzian opinion that the Farbenlehre, being not truly physical, was not truly scientific. Although some may argue even with Heisenberg's formulation (e.g., Jaki 1969), his 1941 lecture still expresses the mainstream of scientific opinion about Goethe's Farbenlehre vis-à-vis Newton and modern science. The question of how Goethe's struggle might be continued has nevertheless received very little attention.

In addition, by casting doubt on the common explanations for Goethe's failure in physical science – his lack of mathematics, his failure to be objective, the difference between the poet and the scientist – without disagreeing with the idea that Goethe failed, Heisenberg leaves us without any explanation of the reasons behind Goethe's mistakes. For granted that there are many different aspects of the world that demand different kinds of sciences, and that the Newtonian theory claimed to account for aspects of the world that it cannot really explain, why did Goethe not state this criticism and then begin developing an appropriate science for that aspect of reality he was truly concerned with? That is, why did Goethe criticize and try to displace the theory of Newton in the first place? Surely this ought to be one of the initial questions we ask when studying the Farbenlehre; but it is doubtful that we can answer it with any rigor if we proceed immediately to vague generalities, such as the typology of poet and scientist or the various aspects of reality, or to peripheral issues, such as the inner workings of Goethe's psychology or his resentments. Yet by asserting that the matters of detail have been settled in Newton's favor and that nothing can be gained from an investigation of the separate rights and wrongs, Heisenberg seems to deny access to what, on the face of things, is the most natural way to determine the reasons for Goethe's apparent failure in physical science – that is, by ferreting out the errors in the works on color, by analyzing the arguments he produced against Newton, and by examining how exactly he justified

his alternative science. On the contrary, the writings of Newton and Goethe should be examined to define as exactly as possible the issues involved and to determine where the proper boundaries of the science of color fall according to their interpretations.

If Heisenberg's critique of the traditional explanations of Goethe's failure is valid, then what remains of the tradition is chiefly the conviction that Goethe committed a fundamental error; a clear notion of what produced the error is absent. Yet in the controversy over Goethe's Farbenlehre, despite the constant refrains that Goethe's errors are clear and essentially all matters of detail are settled, very few writers have considered the errors in detail. The accusation is an assertion, not a demonstration. The literature about the Farbenlehre is full of wonderment that only rarely leads to circumspect investigation.

The Farbenlehre is still shrouded in a number of mysteries, none of which is more perplexing than the question of why Goethe felt compelled to diverge from the Newtonian theory. If we could give a reasonable, well-documented answer to this question, we might also gain insight into what Goethe hoped to achieve with his alternative science. On the other hand, some kind of adequate understanding of what Goethe was attempting positively may be prerequisite for grasping fully the motives that led him to reject Newton's optics. At least in principle, we ought to be able to pose the questions separately, even if we are ultimately compelled to acknowledge that they are intertwined. Furthermore, it is improbable that every aspect of Goethe's criticism of Newton depends on the whole of the Farbenlehre and vice versa, so that at least some of his polemic may be salvageable whatever one thinks of the adequacy of the Farbenlehre. Once we are in a position to judge better the right and the wrong, the just and the unjust, perhaps we can understand why Goethe resorted to polemic in the first place. To reach that end, we must set aside, as much as we are able, the excesses of passion that have unfortunately ruled so much of the controversy. Goethe and Newton were both men of prodigious intellect and ability. It would serve us well to keep this in mind and, at least provisionally, to assume that both understood what they were doing. Even if ultimately we conclude that it is proper to ascribe their differences to the one's being a scientist and the other's being a poet, we must beware of denying to either a share in capacities that are characteristic of all human beings.

Color theory, color phenomena

Replicating Newton's discovery in a rough and ready way is fairly easy. If you take a triangular glass prism with a large refracting angle (close

to 60 degrees), you can catch a beam of sunlight entering a window and observe the spectrum (or spectra, since there are several reflected and refracted images) cast on the wall, ceiling, or floor. To be more exacting, we would need to exclude as much as possible all sources of extraneous light, so that only direct sunlight would be admitted. The light would shine into a long room (15 to 20 feet from window to wall) through a small circular aperture at the window. (Of course, the aperture needs to face the sun.)

Reproducing what Newton called his crucial experiment, however, requires considerably more effort. We need two boards with small apertures, two prisms with large refracting angles, and a way to fix one of the prisms rigidly in place. The first prism would be held at the window-shut aperture; part of the refracted light would pass through a small aperture in a board fixed close to the first prism; perhaps twelve feet further along would be fixed another board with a small aperture; immediately beyond this there would be a second prism fixed rigidly in place to receive the ray of light and refract it in the same direction as the first prism (see Fig. 1.1). With practice we can learn to rotate the prism so that different colors are cast on the hole in the second board and thus refracted a second time. Because the two boards and the second prism are fixed in place, the angle at which the light strikes the second prism will be constant, no matter what color light from the first refraction we cast upon the aperture in the second board; despite this equality of the incident angle, the light will be refracted to different degrees by the second prism. Light that comes from the violet extreme of the first refraction's spectrum will be most refracted, from the red extreme least refracted; the intermediate parts will be refracted intermediately. Consequently, white light consists of many different colors of light that have different degrees of refractibility or, to use Newton's term, refrangibility.

Another demonstration entails reproducing the first experiment of Newton's *Opticks*, in which we need only put side by side against a black background two rectangles, one an intensely saturated (dark) blue, the other an intense red, and observe them through a prism. We will see that they are no longer side by side, the blue rectangle being apparently moved further away from the line of sight than the red. Once more we see that light is differently refrangible, and according to color.

This doctrine of differential refrangibility appears to have some decisive consequences for the science of color. One is that color, or more precisely the quality of producing color, is inherent not in physical bodies or in the eye but in the rays. First, the colors of the spectrum are not the colors of any body; rather, they are produced from what seemed originally to be white light. Second, if we illuminate a body with homogeneal light (what we usually call monochromatic light, radiation of a single wave-