

Goethe and the Poetics of Science

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In Representative Men, Ralph Waldo Emerson presented Goethe as the prototype of the writer elected by nature, and he identified Goethe's specific genius as "putting ever a thing for a word." But Goethe's talents as writer and poet have long seemed to scientific readers to undermine his efforts to be a scientist, and to talk of his, or any, poetics of science would involve a category mistake. But putting things to words—that is, filling and structuring what we say about the world with the content of experience—is what Goethe's investigations of nature aimed at. Considered as a philosophy of science, his method gives robust meaning and contemporary relevance to the term "poetics of science."

Let the words of Ralph Waldo Emerson, from the book *Representative Men* (1850), serve as prologue.

Emerson presents a vision of six great men, whose use and example is to help bring about greater men. The six representative men are Plato, the Philosopher; Swedenborg, the Mystic; Montaigne, the Skeptic; Shakespeare, the Poet; Napoleon, the Man of the World; and, as conclusion, Goethe, the Writer. "I find a provision, in the constitution of the world, for the writer or secretary, who is to report the doings of the miraculous spirit of life that every where throbs and works. His office is a reception of the facts into the mind, and then a selection of the eminent and characteristic experiences" (394).¹ "Men are born to write....Whatever [the writer] beholds or experiences, comes to him as a model, and sits for its picture" (395). "This striving after imitative expression, which one meets every where, is significant of the aim of nature, but is mere stenography. There are higher degrees, and nature has more splendid endowments for those whom she elects to a superior office; for the class of scholars or writers, who see connection where the multitude sees fragments, and who are impelled to exhibit the facts in order, and so to supply the axis on which the frame of things turns" (396). To such a superior office, according to Emerson, nature elected Goethe.

This writing of nature, of the world, oriented along the axis on which the frame of things turns, suggests that the Writer is engaged in a kind of natural science. But of course it also suggests, in a poet's hearing, matters such as rhetoric and poetics. To the modern sciences these words sound alien, even antithetical, to scientific knowing. What need is there for rhetoric, when one deals in truth, or at least aims for it? What does science have to do with poetry, so that something like poetics would be in order? Talking of

these things seems to draw us away from science's proper goals. However (a more cynical respondent might continue), the title "Goethe and the Poetics of Science" might in fact be more appropriate to a treatment of Goethe's scientific work than would "Goethe and the Truth of Science." What the great German poet propounded as science seems more poetry than truth, more poetics than science.

Poetics and science may not be mutually exclusive. But what poetics has to do with science's truth is not evident at first glance, perhaps not even upon some reflection. What *do* poetics and science (natural science) have to do with one another? One might suspect that the phrase "poetics of science" is based on a category mistake: science is to be treated as poetry, or at least as poetry-like. Of course, if one made the inverse claim, that there is something scientific or rather cognitive about poetry, that would appear relatively uncontroversial, especially to an audience with a deep appreciation for the liberal arts. But to imply that science is or, worse, should be poetic is to confuse categories. To put it rather fancifully, the madness inspired by poetry's muse must not affect the sobriety of science.

1.

If you read much of the critical literature on Goethe's scientific writings you will find this to be a recurrent fancy: that Goethe was an enthusiastic poet-interloper in the dispassionate domains of science. The fancy rests on a dual or rather a dichotomous stereotype in which the poet and the scientist stand as forever opposed characters. Stereotypes are not always simply false, of course; they are limited, degenerate abstractions that may preserve some resemblance, in one way or another, to the originals from which the abstraction was long ago made. But if you have more than a passing acquaintance with who Goethe was, you know how questionable this stereotype is when applied to him.

Emerson applied a very ample stereotype to his representative man Goethe: Goethe was the representative of the calling of the writer. If you open a dictionary with biographical entries you will see Goethe described in what at first glance seems a similar way, as a German poet and dramatist, born 1749, died 1832. The authoritatively primary category for understanding him is thus 'poet.' A brief English-language encyclopedia entry might tell us that this son of a well-to-do Frankfurt family became the German Shakespeare and add that he engaged in many activities in his lifetime, from lyric poetry to painting, botanical research, technical administration,

and European diplomacy. We would thus be faced with a profusion of categories for grasping his life's significance. Still, because of our need for categorical certainty and simplicity in our stereotypes, we tend constantly to return to the first: Goethe as poet. Similarly, when we consider figures like Isaac Newton or Albert Einstein, we align them with the category 'scientist,' no matter what else we know about them and their life's activities. Unlike Emerson's rich categories, however, the poet and the scientist of our dictionary and encyclopedia entries are taken according to the lowest common denominator.

The question about the possibility of and need for a poetics of science can be translated, albeit imperfectly, into the question whether the scientist and the poet can coexist. Is a Newton or an Einstein compatible with a Goethe? The deeper sense of this reformulated question is this: can the characteristics that we associate with a Newton or an Einstein coexist with those of a Goethe, not in the indifference of two individuals each going his or her way, but in the same person, in the same soul? Even more: can these characteristics be harmonized in the same person, indeed can the characteristics that produce the excellence of the one support and contribute to the excellence of the other?

I fear that by beginning with a dichotomy of the stereotypes poet/scientist I have fated myself to end with something stereotypical and dichotomous, no matter how these questions are answered. Perhaps the only way to rescue us from the resulting dilemma is to ask about ourselves. I suspect that just about everyone reading this article is to some not insignificant degree committed to the liberal arts. The liberal arts traditionally encompass the subject matters of what we have come to call the arts and sciences, that is, the modern humanities, social sciences, and natural sciences. To pursue the liberal arts is to be committed, in some greater or lesser degree, to the task of studying the full cycle of the world and everything in it—even if this task is observed more in the breach than in the fulfillment.

At some level of our being we aspire to become renaissance women and men. One reason that the figure of Goethe attracts our attention is that (it is said) he was one of the last who could aspire to this status with some hope of success. Nevertheless, a question mark stands alongside his name in particular, both because there are reasons to wonder how far he genuinely succeeded, and because even if he did substantially succeed we can doubt whether it will ever be possible again. How far can such success go in an age of hyperspecialization in every art and science? How effective can the

humanistic side of our undertakings be in a situation where the paradigm of effectiveness is the sciences and the technology to which they give rise?

In his essay on Goethe, Emerson did not overlook the kinds of problems and deficiencies that arise from working in many directions. In his portrait of Goethe he turned them into strengths. Goethe, living in a time of general culture that smoothed down all sharp individual traits; living in an age of culture, an age of poetic writers rather than poets, of clever politicians rather than statesmen, of professors rather than prophets and philosophers, of multitude rather than simplicity: this Goethe

was the philosopher of this multiplicity; hundred-handed, Argus-eyed, able and happy to cope with this rolling miscellany of facts and sciences, and, by his own versatility, to dispose of them with ease; a manly mind, unembarrassed by the variety of coats of convention with which life had got encrusted, easily able by his subtlety to pierce these, and to draw his strength from nature, with which he lived in full communion. (401)

Emerson then goes on to identify the specific character of Goethe's writing:

There is a heart-cheering freedom in his speculation....He had an extreme impatience of conjecture and rhetoric. "I have guesses enough of my own; if a man write a book, let him set down only what he knows." He writes in the plainest and lowest tone, omitting a great deal more than he writes, and putting ever a thing for a word. (402-403)

"Putting ever a thing for a word." The phrase marks the heart of Goethe's genius, the heart of genius that offers us some hope still. It is a practice that goes counter to our latter day, semiotic, and propositionalist tendencies. We are masters of putting words, symbols, and images for things, and of words, symbols, and images for other words, symbols, and images. This mastery is not altogether unprecedented: recall that the advocates of Renaissance complained of the Scholastic tendency to put jargon in the place of reality and to create ever new abstractions to describe and refine other abstractions. They were simply repeating in more rhetorically effective form a complaint that generations of readers of Scholastic writings had already felt and said. But in our time we are facing this problem in histori-

cally unmatched intensity and range, especially with respect to symbols and images. I say problem, although many people perceive it as an intoxicating and liberating opportunity. The place where this problem or opportunity is most acutely felt is in the information explosion, in the technology that is being used to digitize everything as information and to make it widely, if not universally, accessible. This technology is predicated on read- and write-operations and the near-instantaneity of communication. Could this communication, this electronic reading and writing, supplant Goethe as the prototype of the Writer?

Emerson turns this around: not putting words for things is the key task of the writer, but putting things for words. What is the secret that Emerson has put his finger on, this ever putting a thing for a word? It is hard for us to feel the urgency and inevitability of this question, but we must if we are to identify the source of the strangeness and the power of Goethe, what is alien in him as well as what is fresh. From this source derives also what I have called the poetics of science.

2.

Goethe remarked in his old age that of all the accomplishments he had achieved, the one that was most important to him was scientific: his discovery of the truth in the difficult matter of the doctrine of color.² But his discoveries here were controversial from the moment he published them, and the majority of commentators would say that his self-assessment was quite simply wrong. They would argue that he was really nothing more than an amateur of science—in fact an amateur of many sciences, beginning with botany and geology and extending to optics and color theory, comparative animal morphology, meteorology, and biology (the name of which, ‘biology,’ Goethe apparently coined).

It is not my intention to rehearse here why these commentators are mistaken about Goethe’s work in optical and color science and about whether it is right to dismiss him as merely an amateur of science (unless that is taken to mean that he studied scientific subjects out of love). Anyone who is interested can read this in a book I published nearly two decades ago, *Goethe contra Newton*.³ I will only say that here, too, the understanding of Goethe has been dominated by trotting out stereotypes, stereotypes that are not only inappropriately applied to the reality of Goethe’s work but also inappropriate in themselves because they are based not on things but on caricatures. The deep irony is that Goethe’s science did not suit the age

because he took seriously the empirical and methodological demands that his contemporaries professed but did not follow, and his conception of science was formed and transformed by his own studies of the historical development of the sciences that are unmatched in profundity and sophistication by anything that preceded and by most of what followed.

Goethe recognized that science is not simply discovered, it is made. Having said so much, we would seem to align him with, say, a social constructivist theory of science. In the strongest versions of social constructivism, science implements an ideology. Far from being a dispassionate discovery of nature's laws, it is a construction imposed on nature—indeed, nature itself is a construction imposed on experience. I suspect that Goethe would be extremely interested in theories of social constructivism. But he had too carefully schooled an empirical sense—to put it another way, he had performed too many experiments and observed nature for too long—to be seduced by the thought that science was socially constructed and nothing else. Goethe is the thinker to whom *all* sorts of thinking that say, “it is this and nothing else,” *all* sorts of reductionism, were alien. He was instead a thinker of the “and this, too.” For Goethe there is an aspect of social construction in science, but this is only one aspect of the more comprehensive sense in which science must be constructed, in analogy to how nature is *construed*.

Science must be constructed in analogy to how nature is construed: what does that mean? Elucidation must wait until the next section. But invoking the theme of the construction of science already opens a context in which it makes sense to talk about the poetics of science.

A poetics, first of all, is a theory of poetic composition. A traditionalist definition of poetics might describe it as the rules of composition that give rise to all the genres. To put it in a somewhat more modern vein, poetics studies the different expressive possibilities of works of art, especially the possibilities of form. More generally, it is a theory of poesis: of how things that are made by art are put together and why, and how different kinds of making lead to different results, in particular to different genres and styles of works (especially, but not solely, in literature). Given this definition it would seem that science is not in need of poetics. The number of genres of science, if they may be called genres, is small: the short communication and response (e.g., the note and the letter), the journal article, the monograph, the textbook. Unlike genres of the arts, these are dominated by the purpose of communicating information in as economical and well focused a way as possible. So, for example, the scientific note conveys information that it is

urgent to convey to those intensively active in the field—for instance, the occurrence of the first flares that announce the beginning of a new phase in solar activity—and also things that are quite striking but that are not yet well understood—for example, when an unexpected source of cosmic radiation is detected by a satellite. The journal article, usually addressed to specialists but also to investigators in related specialties, is carefully structured. It places scientific work and discoveries in the context of established theories and research programs, explains methodology and experimental setups, reports data, discusses conclusions that can be drawn therefrom, and projects possible new consequences and projects. The monograph sums up a field for experts and advanced learners; the textbook introduces a field to those who are on the way to expertise.

These genres of scientific writing are for the most part standardized, so that one might ultimately be inclined to grant that a poetics of science exists but that it is almost trivial. If poetics has to do with the outward form only, this is probably true. With literature we would be very much disinclined to say that poetics is a matter only of outward form (recall that for Aristotle the poetics of tragedy involves the formation of an emotion and its catharsis, hardly a merely outward form). Literature of the same genre would be drearily the same if this were so. The minimal poetics of science would still, however, be compatible with a more various rhetoric of science. Rhetoric, of course, is not poetics generalized but rather a theory of how a message can be varied or differently inflected in order to reach different audiences. The same forms of communication thus can be employed with different effectiveness because of the differences in audience; and different forms, because of the different preparation of audiences, can achieve more or less the same effect. A rhetoric of science seems important and justifiable—it has to do with the shaping and polishing of an already well-developed content in view of the state of mind of the audience. Nevertheless, the rhetoric of science has been almost as little studied as the poetics of science.

The differences between the scientific genres of communication seem not very substantial, then, unlike the differences between the uses of language that give rise to poetry and prose: to lyric, ode, epic; to drama, short story, and novel. One way we explain this to ourselves is to say that all scientific writing must be adapted to the needs of effectively communicating already well understood information, whereas the “rules” of literary composition produce substantially different forms; that is, the form itself is not merely a vehicle of communication but itself constitutes the major shaping mo-

ment of the work's message. If literature were just a means for conveying information, then Shakespeare's plays could be substituted by well-crafted summaries.

There is something defective in the conception of the poetics of science as I have presented it so far, however. What is wrong becomes more evident if we consider an example of a science in which poetics has been foundational. I refer to geometry, which received its first defining formulation in Euclid's *Elements*, some 2300 years ago. In this foundation, a geometrical object has to be carefully delimited and articulated in a step-by-step process that moves from certainty to certainty. Note that I am not saying that an already constituted geometrical truth has to be conveyed as information, and that Euclid hit upon an especially useful rhetoric for presenting it. The formulation of geometrical truth is not just a rhetorical embellishment to already well-established knowledge but is that knowledge in its fundamental formation, generation, and explication. The form is not mere form but the outward aspect of the internal unity of the science. Euclid thus opens our eyes to the fact that poetics can be intrinsic and even foundational to a science.

3.

Let us return to Goethe. In his earliest attempt to systematize his insights into the method of science, "The Experiment as Mediator between Object and Subject," an essay (probably from 1793) that expressed the results of his first foray into optics and color science, Goethe recommended the practice of mathematicians as exemplary for work in the sciences of nature. It is easy to misunderstand what he means. He is not simply aligning himself with the leading trend in post-Renaissance natural science, the mathematization of nature, or conceiving mathematics as the natural scientist's proper rhetoric.

Newton is a chief representative of that leading trend. Newton's *Mathematical Principles of Natural Philosophy* had shown how to present regularities found in natural phenomena in a form accessible to geometrical and algebraic treatment.⁴ The phenomena themselves are not mathematical, but the laws to which they conform (in this case, the laws of dynamics and mechanics) are expressible in exact mathematical forms and formulas. In his methodological essay, however, Goethe took this as just one legitimate way in which the example of mathematics might be followed. Here are his words from the essay "The Experiment as Mediator":

In the first two installments of my optical contributions I have sought to erect such a sequence of experiments [i.e., ramified through *Vermannigfaltigung*, ‘manifolding’] that first and foremost border on one another and touch one another without mediation; indeed, when one knows and surveys them all exactly they constitute as it were a single experiment, they represent a single experience under the most manifold perspectives.

Such an experience, which consists of several others, is evidently of a higher kind. It presents the formula under which countless individual examples are expressed [*Rechnungsexempel*]. To work toward such experiences of the higher kind I consider the duty of whoever does research into nature; the example of the most excellent men who have worked in this field points us this way, and the conscientiousness in placing the closest next to the closest or rather in concluding the closest from the closest we must learn from the mathematicians, and even where we attempt no calculations we must always go to work as though we owed an account to the most rigorous geometer.

The first thing to notice in this passage is that experiments and experience are the chief concern. When a modern scientist applies mathematics to nature, he ordinarily abstracts from the natural situation, often by using a simplified model that serves as an extended analogy. When Goethe takes the geometer’s practice as a paradigm, he intends chiefly the great care that she devotes to making sure that everything needed is at hand and deployed so that conclusions might be recognized and drawn. The object is less to have a mathematical formula that *abstracts* the relevant considerations from the phenomena than to gain a *deepened* and *more unified* experience of the phenomena (indeed, to some degree the abstracted formula presupposes that one has already achieved a new level of experience). The method of the geometer presents geometrical truths in a way that elucidates their being and nature. Such a method is rhetorical insofar as it is adapted to the human capacity for apprehending truth; it is poetical insofar as it builds and extends the structure of the scientific discipline.

Goethe’s way of science thus aims at an original experience, original in the sense not so much of being unprecedented as of taking or referring things back to their origins and placing them in fundamental relations to other things in the relevant field of interest. Several years later Goethe began using the term *Urphänomen* for the unity of what is experienced as single despite the manifold perspectives under which it appears (*Ur-* as a prefix in

German refers to something original or foundational).

Goethe scholars may not be impressed by yet another invocation of the Urphenomenon. The problem with the Urphenomenon is that if what it signifies is not made as concrete as possible it sounds like a merely edifying, romantic notion especially pleasing to poetic sensibilities but without scientific consequence or, even worse, with tendencies that are antiscientific. No one is against getting in touch with nature, exactly, but well-meaning sentiment often invites ridicule as simplemindedness. So let me give some concrete precision to the concept. My text will be the *Beiträge zur Optik*, the *Contributions to Optics*. It was the experimental preparation for these experimental essays that led Goethe to the notion of unified experience that he expressed in “The Experiment as Mediator between Object and Subject.”

In the *Contributions* Goethe was responding to how Newton first presented his theory of white light and colors. While investigating lenses Newton secured some triangular glass prisms to observe “the celebrated *Phaenomena of Colours*,” as he wrote in the opening paragraph of his letter of 6 February 1672 to Henry Oldenburg, the secretary to the Royal Society of London.⁵ When he noticed that the figure of the spectrum was more elongated than the prevailing mathematical theory of refraction suggested, he began to explore why this discrepancy occurred. Just a few experiments led him to what he termed a crucial experiment: by setting up a series of apertures and using two prisms to refract the light, he showed that light rays from different portions of the spectrum are refracted to different degrees. To put this in the form with which we are most familiar: By refracting sunlight a first time he separated the differently colored components of the white light. When he variously selected portions of this already separated light and directed it to a second prism, he discovered that, with the angle of incidence the same, the red-producing light is refracted least, violet the most; and according as the rays come from intermediate portions of the spectrum, the light is refracted to intermediate degrees. Rays from portions of the spectrum closer to the violet end are refracted more than those further from it. Light is differentially refrangible according to color.

In his *Contributions to Optics*, Goethe takes a different approach to the phenomena of refraction, although, like Newton, he begins with casual observations. Early on he instructs you, the reader, to pick up a prism and look through it. What you will notice is that the field of view's position seems to be shifted by the refraction, and, although you can recognize all the objects in the field of vision, they are fringed with hues other than their

natural, daylight colors. He suggests exploring this phenomenon by simplifying the field using artificial displays, first black and white, then chromatic. These displays help make it evident that the hues produced by refraction are associated with boundaries, and that especially with black-and-white displays the phenomena are quite regular in appearance, although not yet predictable (that is, not until you have undertaken further experimental analysis). He continues simplifying to the point of showing that, if there is no boundary at all (for instance, using a poster that is all white), no colors appear through the prism, but that, if there is a single, straight-line boundary (for instance, with a poster painted half black and half white), colors will appear. If you are viewing the poster with the prism's refracting edge pointed downward and if the black half of the poster is below the white half, you will see the boundary apparently fringed with cyan blue on the side of the white and dark violet on the side toward the black; if the white half is below the black, the fringing colors will be yellow on the white side and red on the black.

Goethe then begins recomplicating the experiments. He views white rectangles on black grounds and black rectangles on white grounds, he varies the dimensions of the rectangles, he increases and lessens the distance at which he stands from the posters, he changes the intensity of illumination, he uses prisms with different-sized refracting angles, he shows that using black or white circles instead of rectangles further complicates appearances, and so forth. Then he goes on to experiments more like Newton's, with beams of light passed through the prism and projected onto a screen; once again he identifies and varies the circumstances and describes the changes in the phenomenon to which the variations give rise (for instance, by changing the size of the aperture through which sunlight is admitted into the room, and by varying the distance between the prism and the screen).

It is not necessary to go any further into the details of Goethe's color science. This kind of systematic experimental variation, by which one gains a progressively more comprehensive acquaintance with the full range of phenomena possible in limited circumstances, is Goethe's *fundamental scientific method*, and not just in color science.⁶ By means of the manifold variations of experiments one seeks an overall experience that will be unitary in two ways: in that the experiments performed are progressively evolved from one another by a series of small modifications, and in that one has seen how the small modifications affect and vary the outcome while still remaining basically the same type of experimental phenomenon (for example, the

refraction of light through an aperture). It was from the perspective of this type of progressively unified experience that Goethe felt entitled to criticize Newton's experiments and theoretical preferences. He contrasted Newton's practice unfavorably with Robert Boyle's. In *Experiments and Considerations touching Colours*, Boyle had presented a vast array of prismatic experiments; Newton, on the other hand, presented experiments only to drive forward a narrative that intends to discredit competitor theories and to prove his own. Goethe believed that it was an obligation of the researcher to become fully acquainted with the phenomena in question and to ensure that any theories and generalizations were compatible with their full range and variety. By being very selective of the phenomena, Newton produced an appearance of comprehensiveness that was as much artifice as reality. One can judge well only when one sees all the evidence. The researcher's poetics should thus organize the phenomena and experiments into comprehensible local structures that are subsequently related to one another in a more encompassing structure. Proving a hypothesis is a more limited, rhetorical goal that should be attempted only after the poetical structure has been laid down.

When Goethe detailed in "The Experiment as Mediator" a method of putting what is closest next to what is closest, he was describing the experimental practice he followed in the *Contributions to Optics*. It is not at all antithetical to, though perhaps more strictly organized than, late eighteenth-century observational practice in European experimental sciences. Yet there is a fairly sharp contrast with the practice of the more mathematized natural sciences.⁷ In hardly any sense do the mathematized natural sciences aim to help one *observe* the phenomena in an orderly fashion. Instead, they highlight an observable aspect or even abstract entirely from the observable so that the observable is treated as merely an index of what is invisible—e.g., color becomes an index of a property of submicroscopic light corpuscles, a property called refrangibility. Goethe's practice in the *Contributions to Optics* was to present in as continuous a fashion as possible the full range of phenomena of a single type, with the type being defined as the set of phenomenal outcomes associated with the similar configuration of the elements of the experiment. Completeness, continuity, and unity serve as imperatives in the presentation, although even at this stage of his career he realized that these imperatives could often be satisfied only approximately. One can certainly conceive of different ways of assembling or arraying the phenomena, different ways of composing or constructing them; even so, given the subject of colors produced by the refraction of a single prism, Goethe's fulfills the imperatives of completeness, continuity, and unity tolerably well.

4.

There is a great deal more that could be said, indeed that needs to be said, along the lines we have been tracing. But the question at issue is the poetics of science. I have described two different ways of constructing the science of refraction that not only lend themselves to rhetorical (persuasive) purposes but also involve different notions of scientific poetics. That natural sciences are always constructed by human minds and hands and by instruments that often mimic natural phenomena I take as fact (one does not have to be a social constructivist to say this, only a student of the sciences and their history); that this construction of science carries out some implicit construal of nature seems to be ordinarily the case; that the construction of science is conducted in light of some general or governing principles of construction, a theory of the poetics of science, is therefore a likelihood.

When I talk of the poetics of science, I am in the first instance talking about the principles of the unity of the works of science. But what do I mean by the 'works of science'? They do not have to be writings. The poetics of science therefore does not need to concentrate on the writings of science (indeed, I have already suggested that the writings of science as they fall into genres today are better understood from the perspective of audience reception, that is, from rhetoric, than from poetics). The analogy with literary poetics must not mislead us here. The genres of literature are works of letters, written works. When we ask ourselves what the works of science are, we should think beyond notes, articles, monographs, and textbooks, to bodies of evidence and their organization, to experimental methods, to equipment and instruments, to laboratories, and of course to theories.

Some of these things may not seem to be appropriately labeled "works of science." Schools of writing exist because literature exists and because people want to write good literature; they are not themselves works of literature, except in a figurative sense. A laboratory may be as much or as little a work of science as the school of literature is a work of literature. But we must not be too quickly dismissive of the idea, for example that laboratories are scientific works.⁸ Works of literature could very well be produced without schools of literature and flourish without them, whereas we cannot say that the sciences could flourish without the places where scientific work is done. If we take seriously the past half century of historical and philosophical studies of science, we can hardly assert with confidence that laboratories and laboratory activities are not scientific works or not intrinsic to the conduct of science.

Another way in which modern science is richly productive of works, richly poetic, is in its making of theoretically and practically important phenomena, like the refractive dispersion of light or the amplification of light by the stimulated emission of radiation (that is, the laser). These basic phenomena—perhaps they should be called Urphenomena—are instrumentalized literally and figuratively and fed back into the productive activity of science. I mean, for instance, that in Newton the dispersion of light by the prism is not just a leading phenomenon he investigates, but it becomes a basic technique in further work, so that virtually every future experiment works with light that has been prepared by refractive (or, later, diffractive) dispersion; or the way in which about 150 years later dispersion was literally instrumentalized in the spectroscope, which is routinely used to analyze light and thus to identify the chemical composition of the light source. Here we begin to glimpse that there is a more intimate unity and hierarchy to all the productive activities of the sciences than there is in literature. We cannot, for example, say that the verse couplet is the central product of literature, and everything else is built up from it or related to it; we can, on the other hand, say that certain produced phenomena are basic for all the facts, discoveries, theories, and instruments—and even the laboratory arrangements—of a science.

From the point we have now reached we can recognize that contemporary philosophy of science has in one respect acknowledged the poetics of science, although not under that name or concept. Philosophers of science, at least implicitly since the neo-Kantians and in full-blown glory with the positivists and logical positivists, made *theory* construction and its canons the centerpiece of their project. Perhaps we could even wonder whether in this they were not simply following the pattern set down by Aristotle, for whom the *Prior Analytics* and the *Posterior Analytics* laid down the canons governing the construction of demonstrative knowledge. Their construction of theory concerns itself only with symbolic structures. The real genius of modern science is driven even more fundamentally by teaching us human beings to put things—electrons, experiments, equipment, research facilities—in the place of symbols.⁹

Goethe believed that all research in and presentations of science (let us take this phrase as a more complex way of saying “works of science”) were guided by certain basic intuitions, what in some of his mature writings he called by the French term *aperçus*. When I remarked earlier that the construction of science ordinarily carries out some implicit construal of nature

I had Goethe's notion of these basic intuitions in mind. These intuitions do not come out of the blue, at least not ordinarily; they usually require some long and careful preparation. But when they come, they often come like a bolt out of the blue and are at the heart of the "Eureka!" phenomenon. They are not simply recognitions of what is objectively the case, nor are they to be simply identified with what one might call the subjective realization of the abstraction of an intelligible form. For Goethe, the human being is not a passively objective receptor of the way things are. Each person has certain characteristic contexts for seeing things and certain characteristic ways of trying to put things together, even and especially when he or she is experiencing a thing, an event, a field for the first time. He called these characteristic ways *Vorstellungsarten*, ways or manners or types of conceiving, presenting, and representing things—let me refer to them simply as *Vorstellungsarten*. The intuitions of truth are always accommodated in the experience of the individual to that individual's *Vorstellungsart*.

These ways of representing things are not merely subjective factors that unfortunately color our perceptions. Goethe apparently found a stimulus to the conception of the *Vorstellungsart* from his reading of Immanuel Kant's *Critique of Judgment*, precisely in those parts of the work that discuss what lies at the heart of the mind's search for larger unities and purposes in nature than those immediately presented by sense perception. What Goethe's study of the history of science had persuaded him of was that there are recurrent types of searching for and expressing some of these larger unities. For example, atomism is not just a theory but also a recurrent manner in which a certain type of intelligence tries to comprehend the basic phenomena of nature. So are mechanism and mathematicism; so are dynamic, developmental ways of conceiving phenomena; so are genetic ways of unifying present phenomena with the account of their origins.

The *Vorstellungsarten* make sense of why there has to be poetics in science. They identify fundamental approaches to natural things according to the aspects of their self-showing. These aspects for the most part allow a relatively autonomous development: the establishment of a field within which certain objects and events reliably take place with a degree of autonomy. We can examine, portray, and organize the physical universe kinematically, purely in terms of the motions we see there. This kinematic *Vorstellungsart* logically and temporally precedes the mechanical *Vorstellungsart*, which tries to understand kinematics in terms of gravitational (and other) forces. Although most people might think that kinematics is thereby completely

reduced to mechanics, that has only a partial and schematic truth. In fact, when we re-attend to the notions of things in a more precise way (which logically and temporally presupposes the prior development of kinematics and mechanics) we discover that we have to (1) further develop and refine our kinematics (how do the chunks of matter in Saturn's rings really move? how do electrons actually travel through space?) and (2) look to questions of the history of the universe—the genetic or developmental *Vorstellungsart*. Disciplines and subdisciplines of the sciences are thus based on *Vorstellungsarten* and their simple combinations, because they open up new ways of grasping objects, their behaviors, and the principles of their unities.

In a first approximation one might call *Vorstellungsarten* the fundamental forms or styles of human subjectivity. But that still misses their character, for two reasons. First, Goethe does not believe that an individual's mind typically presents a single *Vorstellungsart*, much less a single one in pure form. Instead, each person's mind typically reflects many *Vorstellungsarten* and has the capability of developing new ones, at least in a secondary and rudimentary manner, that will allow him or her to grasp how those who have a different way of seeing things experience the world. Thus a scientist who thinks in terms of *analytic* methods might be challenged to stretch his conception by a master of *synthetic* understanding; a mathematical topologist, accustomed to dealing with objects as continuously deformable in space, might be challenged to expand her approach by another mathematician who has found ways of applying discrete techniques to the same phenomena. One might then want at least to adjust the first-approximation definition and to call *Vorstellungsarten* fundamental forms of intersubjectivity, since they are the basis for different people seeing things in typical ways, or at least for allowing people to recognize key differences in their respective ways of seeing and conceiving things.

The second reason for correcting the first-approximation definition has to do with the constitution of objectivity. Like present-day phenomenologists, Goethe contended that the phenomena are prior to the constitution of both subjectivity and objectivity. Subjectivity and objectivity are correlative. So, for example, the kinematic approach to the universe is not just a way of conceiving objects but of regulating subjectivity so that it orients itself primarily to objects under the aspect of their motions. An observer, to develop kinematics, must attune himself to this aspect of the phenomena. This is different from the attunement that looks for the clues of the genesis or development of objects out of previous objects and circumstances, which

is different from the attunement that is constantly alert to forces among elementary objects. If we cannot say exactly how many possible attunements or *Vorstellungsarten* there are, or how many are plausible in a particular field, we can nevertheless suspect that they are many. And although we might expect that there are significant relationships of priority and posteriority among them, we cannot always expect this to amount to the total reduction of one or several to another.¹⁰

Goethe, a firm believer in multidisciplinary approaches to the things of nature, recognized that there will always be fruitful interactions between different approaches and their corresponding disciplines, and that some will turn out to be more basic or revealing than others. In his color studies he claimed that the physiological approach is most basic, but that did not in any sense mean that all color phenomena could be reduced simply to activities of the visual system.¹¹ In his morphological studies the fundamental units were the forms of animals and plants understood in connection with the forms of their basic organs and parts, but he expected chemistry and physics to reveal important facts about living things. Thus the *Vorstellungsarten* lead to a complex organization of the sciences according to what each approach contributes to understanding the phenomena, according to what each reveals by highlighting different aspects, levels, and elements.

5.

I mentioned earlier that Goethe's understanding of science was far more sophisticated historically than anything that preceded or followed it. He knew, long before the critical efforts of twentieth-century philosophers and historians, that the most diverse forces and influences go into the making of science: social movements, intellectual fashions, religious convictions, personal predilections, and a host of other things. More basically, however, he thought that sciences were constructed on the basis of the ways of conceiving and presenting things, *Vorstellungsarten*. Newtonian color science privileged the mathematical, the atomistic, and the mechanical ways of conceiving the world and its unities; his own color science, his *Farbenlehre*, instead reflected a dynamic and genetic character. He pointed out that every language has different capacities and incapacities for expressing the character of phenomenality—no Latin speaker could in the last analysis break free of the nominalizing tendency of the language, whereas the ancient Greek could avail himself of the dynamism of verbs turned into nouns. Those who think Goethe was an enemy of mathematics cannot be aware of his invocation of

the possibility that a higher mathematics could symbolically express delicate phenomena of nature that the crudeness of arithmetic and elementary plane and solid geometry cannot. Anyone who is interested in pursuing these points further must read his *Materials toward a History of the Doctrine of Color*, which, unfortunately, has not been translated into English.

In his mature science (after 1798, say), Goethe recognized that there is ultimately no completely neutral way in which the phenomena of a scientific field can be presented. Even the *Contributions to Optics*, which he was determined to keep free of theoretical bias, he later adjudged to be tinged with his particular way of seeing things. This reflection might lead us to a certain despair that Goethe finally had to rest content with a sophisticated version of relativism: I see things my way, you see them yours. This conclusion would be hasty, however. That truly neutral presentations of fact are unattainable is not a reason to abandon attempts to steer clear of theoretical partiality; that a presentation can never be complete does not make pointless the effort to be as comprehensive as possible, as, for example, the first part of his *Zur Farbenlehre*, the so-called “Didactic Part,” attempted to be. The “rules” or “ethics” governing the poetics of science demand that one search for unities in the appearances and that one be as comprehensive as possible in laying out the elements and the field that theories must explain.

It is hardly possible for me to do more than mention some of the larger aims of Goethe’s poetics of science. First of all, it must be understood as a cognitive poetics of *nature*. As a believer in analysis Goethe can urge us as investigators into nature to look for what are the elements and foundational principles of what we experience. But as a nonreductionist he does not believe that we can ever give a comprehensive account analytically, for nature is constantly productive in its combination and recombination of elements. Something new and unforeseen may emerge from the interactions of what we have analytically isolated. One might say, not at all outside of the spirit of Goethe, that precisely what differentiates physics from chemistry is that physics can take, say, atoms in their indifference to one another, whereas chemistry is concerned with the specific and in some sense unpredictable result of bringing together atoms into chemical combination. Water and all its properties are not simply predictable on the basis of knowing about oxygen, hydrogen, and the laws of valence bonds, not even given all the resources of twenty-first century physics and chemistry. In this sense, any sciences that trace out newly emergent phenomena must find ways to form the experiences of investigators into larger unities that make the world richer

and (we hope) more intelligible as well. Probably richness will always outstrip intelligibility, however. Our productivity, creativity, and technologies will likely always exceed our understanding. The innovations we cultivate and the unexpected events we encounter will provide new objects for investigation and new models for understanding, and occasionally new ways of conceiving things, that in a constantly refreshed feedback cycle will further amplify our sense that nature's intelligibility and creativity exceed our grasp.

I will end with a simple reflection on Emerson's claim that Goethe was putting ever a thing for a word. Goethe's scientific work strove not to weave a web of words but rather to use words to give us access to things. Those who read his writings on color might complain that often all he does is have you perform experiments you already know about. That is both right and wrong. He instructs you in the technique of doing the experiments in the most manifold ways; many of the phenomena you have already seen, but some you have barely noticed, some you know only by hearsay, and others you have never before managed to gather into a dynamic, living relationship. By working to view them whole you arrive at a different, more varied, and more integrated perspective. In this quite precise sense, Goethe puts things in the place of words, of hypotheses, of merely verbal or formulaic theories. He puts you at a vantage point from which you can become critical even toward yourself and your most deeply felt convictions. That is, he can help you develop the most mature and sophisticated of intellectual virtues, self-irony, the one that is rarest but most essential to honest scientific work because it is the maturest fruit of a critical attitude.

By these means you will be brought into touch with things, with nature, and with yourself. Your words will become more responsible in the way they present things and more responsive to those things. This is the furthest thing from relativism, because it is a way of relating things that puts us into a deep, original, and ample relation *with the world*, a relation that aims to make us inhabit the world more sensitively, more imaginatively, more intelligently. To put a word in the place of all these other words: to make us live more truthfully, more fully in the truth of nature and its amplitude.

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Notes

1. The parenthetical page numbers refer to *The Works of Ralph Waldo Emerson*, 4 vols. in one (New York: Tudor Publishing Company, 1930), 2: 223-414.

2. See Goethe's conversation with Johann Peter Eckermann of 19 February 1829.

3. Dennis L. Sepper, *Goethe contra Newton: Polemics and the Project for a New Science of Color* (Cambridge: Cambridge University Press, 1988).

4. To the calculus as well, although Newton's actual use of calculus in the *Principia Mathematica* was conservatively cast in geometric form.

5. The letter was published in the 19 February 1672 issue of the *Philosophical Transactions* of the Royal Society of London. An annotated version can be found in *The Correspondence of Isaac Newton*, ed. H. W. Turnbull et al., 7 vols. (Cambridge: Cambridge University Press for the Royal Society, 1959-1976), 1: 92-102.

6. In botany one cannot so easily vary the conditions in a carefully measurable and controllable way, yet precisely because of that one has to accumulate as many instances of, say, the patterns of growth to be found within a species as one can manage, by direct experience and from the reports of others.

7. For an extensive discussion of the different traditions of empirical and mathematized sciences, see Thomas Kuhn, "Mathematical versus Experimental Traditions in the Development of Physical Science," in *The Essential Tension* (Chicago: University of Chicago Press, 1977), 31-65.

8. See, for example, Joseph Rouse, *Knowledge and Power* (Ithaca, N.Y.: Cornell University Press, 1987).

9. A pioneering work in this sense is Ian Hacking's *Representing and Intervening*.

10. It seems to me that philosophical reflection on the character of *Vorstellungsarten* and attunements needs to consider Martin Heidegger's account, in *Being and Time*, of *Befindlichkeit* (translated with woeful inadequacy as 'state of mind') and *Stimmung* ('mood')

or 'attunement').

11. This is what Arthur Schopenhauer, who had studied color with Goethe, argued, to Goethe's consternation, in his 1816 essay on seeing and colors.

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