Ten of the chapters in this volume report a variety of experiences with the SMPY talent search program, ranging from longitudinal evaluations to descriptions of special programs for rural talented students and a special program for gifted girls.

The intellectual rationale for this accelerative educational strategy is presented in the chapter by Robinson, to whom the volume is dedicated. He points out that there are three well-accepted principles of child development: learning is sequential and developmental, teaching requires assessment of the individual's status in that developmental sequence, and there is a wide range of differences in how rapidly students of the same age pass through that developmental sequence. Given these three principles, Robinson then raises a fundamental issue, "How can schools defend a rigid age-grade program insisting that all ten-year-olds must be in the fifth grade?"

Pollin's chapter reviews data on the socio-emotional status of students who have been in the SMPY program and concludes that there is little or no evidence available that would suggest that emotional disturbance was a consequence of acceleration of either content or student. This finding is supported by a longitudinal evaluation of SMPY's first class by Benbow, Perkins, and Stanley. The participants accelerated their education more than nonparticipants, expressed greater interest in mathematics and science, and felt good about their participation in the program. Lunny describes a mathematics acceleration program in a rural county where evening classes supplemented mathematics courses that the students attended during the day. This program appeared to be favorably received and represents an interesting and unique method for providing help to gifted students in rural areas.

Fox, Benbow, and Perkins report on a special accelerated mathematics program designed especially for girls. One of the earlier findings from the Talent Search program was that talented girls scored significantly less high in mathematics on the Scholastic Aptitude Test than boys. Consequently, special attention has been given to the stimulation of motivation and interest in mathematics in girls. This included a special program that enrolled only girls so they would feel no male competition or dominance that may have been inhibiting in the past. Unfortunately, the accelerated math program for girls reported here did not yield strikingly successful results. This outcome suggests that there remains a complex series of social and psychological factors that may be inhibiting girls from the full use of their mathematical talent and that are difficult to eradicate.

As is often the case in a volume that translates a conference into print, the contributions are uneven and often redundant. A chapter by Michael that purports to correlate creativity and mathematical talent is less than enlightening. Since the "creativity" measures used are suspect in both validity and reliability, the comparison reported has little meaning.

Nevertheless, it is useful to have a variety of results about a major talent search program such as the SMPY program in one volume. The overall results of these studies strongly suggest that there is room for the more rapid growth of mathematical understanding in identified talented youth without observable negative consequences. We can apparently live up to, without ill effects and with some tangible gains, the educational principle that each child, even mathematically talented children, should be given the education he or she needs, at his or her own developmental level.

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Newton on Optics

The Optical Papers of Isaac Newton. Vol. 1, The Optical Lectures, 1670–1672. ALAN E. SHAPIRO, Ed. Cambridge University Press, New York, 1984. xx, 627 pp., illus. $135.

The statutes governing the Lucasian chair of mathematics at Cambridge required its incumbent to lecture on "some part of Geometry, Astronomy, Geography, Optics, Statics, or some other mathematical discipline." Appointed to the chair late in 1669, Isaac Newton chose to follow the example of his predecessor, Isaac Barrow, by lecturing on optics. The choice of topic is not surprising, since during the previous few years Newton had read the major treatises on optics, carried out a number of original and revealing experiments, and begun to forge his own novel theory of light and colors. Stimulated by the need to prepare a series of lectures, Newton organized and expounded the fruits of his research on a broad canvas. Among the manuscripts at Cambridge are not one but two results of this effort, known collectively as the optical lectures; the first (known here as the *Lectiones opticae*) was begun shortly after Newton's appointment to the Lucasian chair, and the second (the *Optica*) is an altered and extended version that was mostly completed by early 1672. It was also early in 1672 that Newton presented his theory of light and colors to the Royal Society of London. However, his major treatise on the subject, the *Opticks*, was not published until 1704, and the *Optica* first appeared posthumously nearly a quarter of a century later. Although there have been published versions of both the optical lectures, these earlier editions fall far below the standard required by modern scholarship.

For some time scholarly editions have been needed not only of the optical lectures but of Newton's optical writings in general. Many important manuscripts remain unpublished, but perhaps the most serious omission is an adequate edition of the *Opticks*. To remedy this situation Cambridge University Press has planned a three-volume edition of Newton's optical papers. This first volume contains the optical lectures, and later volumes will encompass Newton's other optical writings, including the manuscripts for the *Opticks*.

In the present volume, capably edited by Alan E. Shapiro, the *Lectiones opticae* and *Optica* are transcribed with facing English translations. The texts are prefaced by a useful synopsis of their contents, indicating the major differences between the two texts. There is also an introductory essay in which the editor briefly explores the relationship between these two manuscripts and also the relation of the optical lectures both to Newton's other writings and to the optical treatises with which Newton was familiar. The text is elaborated by useful notes, which, likewise, are principally concerned with the relationship between Newton's texts. This emphasis reflects one of the prevailing preoccupations of the Newton industry, but it is slightly disappointing to find that other aspects of the text, such as Newton's use of language and the provenance of the key terms he employs, are not explored.

Although these optical lectures were

written when Newton was in his late 20's they convey his excellent command of the subject and provide insight into his masterly treatment of problems in optics. An appreciation of Newton's mastery must take account of the details of his work as much as the broader themes in these lectures, but I will concentrate here on the latter.

Near the beginning of these lectures Newton reported having discovered that the rays of the sun's light "differ from one another with respect to the quantity of refraction." This discovery not only controverted other theories of light and accounted for the imperfection of refracting telescopes, it provided Newton with his point of departure for two different, though related, investigations. One of these lines of investigation concerned color; Newton discovered a correspondence between color and refrangibility, demonstrated the immutability of color, and showed that color is innate to unrefracted rays of sunlight and is thus not a product of refraction. In this part of the text, which is largely concerned with experiment, Newton investigated a host of related phenomena, including the decomposition and recomposition of white light and the colors of natural bodies. In the *Optica* this dissertation on color was extended to include the musical division of the spectrum, boundary colors, and those obtained from curved refracting surfaces.

Newton's other line of investigation concerned the mathematization of the phenomena of refraction. Starting with experiments to measure refractions at a prism set at the position of minimum deviation, Newton soon proceeded to calculate refractive indices and to construct a law of dispersion. With the aid of these relationships he then made an extensive mathematical analysis of refraction at plane surfaces and in the *Optica* extended this discussion to include curved surfaces. Of the many important results Newton obtained, his calculation of spherical aberration and chromatic aberration at a curved surface—which relates to the problem of the telescope's imperfection—are among the most impressive.

The increased availability of these texts will make them the subject of much close historical analysis. Even a cursory study of them, however, reveals a deep problem concerning Newton's proclaimed intentions. In the third of the *Lectiones opticae* Newton challenged the view in which colors "are thought not to pertain to mathematics" and then proceeded to argue that just as astronomy, geometrical optics, and mechanics belong to mixed mathematics, so the science of colors "must be considered mathematical, in so far as they [colors] are treated by mathematical reasoning." This program of bringing natural phenomena within the domain of mathematics provides a framework within which to read large parts of Newton's science, including, of course, the *Principia*. The historical importance of this highly successful program has been rightly emphasized, and some historians have even called it the "Newtonian style."

Though it is undeniable that Newton developed optics considerably by bringing the study of color within mixed mathematics, there is an intrinsic problem whether color can be mathematized in the same way as, say, positional astronomy. Whereas the positions of planets can be measured colors cannot. Certainly numbers can be attached to colors, but there are many possible (and usually inconsistent) color scales ranging from the codes used by paint manufacturers to the associated measure of frequency as generally employed by physicists. There was thus a philosophical problem underlying Newton's project, but Newton also encountered another type of problem.

In many of these lectures Newton utilized refrangibility as the mathematically expressible parameter connected with different color-making rays. The major difference between the structure of the *Lectiones opticae* and that of the *Optica* pertains to this relationship. In both of these texts Newton began by discussing his discovery that rays of light differ in their degree of refrangibility. In the first text he then proceeded to his dissertation on color, only subsequently turning to the mathematical analysis of refraction. In the latter text the order was reversed. This change is significant since it indicates that by 1672 Newton had recognized that in his program to mathematize colors the mathematization of refraction had logical priority.

Although Newton was successful in forging a mathematical theory of refraction this should not be interpreted as the sole axis of his program to mathematize color. Though most of his dissertation on color was directed to establishing nonquantitative propositions concerning the nature of colored light—and thus is not directly subsumable under the label "Newtonian style"—Newton attempted in the *Optica* (part II, lecture 11) to assign numbers *directly* to the divisions between the seven colors of a solar spectrum obtained by refraction through a glass prism: "Everything appeared just as if the parts of the image occupied by the colors were proportional to a string divided so it would cause the individual degrees of the octave to sound." Newton's preference for dividing the spectrum according to musical intervals is revealing with respect to his metaphysical presuppositions, but it—like the similar strategy he elsewhere adopted when discussing the color circle and the colors produced by thin and thick plates—can be interpreted as part of his "mathematical way of reasoning" (to quote a relevant section in the *Opticks*).

Thus in the *Optica* Newton offered two ways of mathematizing color—by means of refrangibility and by dividing the length of the spectrum. His next move was to combine the two into a dispersive law so as to assign numbers to the sines of the angles of refraction for each color interval. Having discussed refraction through a glass prism he then utilized the same procedure to calculate refractions from air into water, but in this latter case he noted that "those determinations are not precisely geometric." There is thus a strong sense in which Newton failed to achieve his aim of creating an exact science of colors in these optical lectures, and, as Shapiro has shown (*Archive for History of Exact Sciences* **21**, 91–128 [1979]), the problem of discovering the law of dispersion subsequently exercised Newton considerably but was never satisfactorily resolved.

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Earlier Explorations

Certain Philosophical Questions. Newton's Trinity Notebook. J. E. McGUIRE and MARTIN TAMNY. Cambridge University Press, New York, 1983. xii, 519 pp., illus. $84.50.

With the publication of editions of the correspondence, the mathematical papers, the optical papers, the papers on dynamics, variant readings of the *Principia*, and other texts, the growing body of published manuscripts of Newton's is beginning to resemble a "Collected Papers." McGuire and Tamny's volume constitutes a measurable stride in that direction by bringing out two manuscripts that everyone familiar with Newtonian scholarship agrees are of immense importance.

Quaestiones quaedam Philosophicae, *Certain Philosophical Questions*, is the title Newton put at the head of an extended section of the notebook he kept for philosophical studies during his un-