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(b. Milverton, Somerset, England, 13 June 1773 : *d.* London, England, 10 May 1829)

natural philosophy.

Young made many discoveries in natural philosophy and physiological optics, and he was one of the first persons to translate Egyptian hieroglyphics. He is most famous, however, for his attempt to win acceptance for an undulatory theory of light. His failure scientific colleagues initially did not share his interest in that theory, nor were they ultimately convinced by his discoveries or arguments. Young's achievements, as well as his failures, must be understood in the context of his education, heterogeneous career, and personality as well as in terms of contemporary scientific evaluations of his theories.

The eldest son of Thomas Young, a mercer and banker, and of Sara Davis, Young was raised as a member of the Society of Friends and was largely self-educated in languages and natural philosophy.[1] He learned to read at age two : and by the time he was six, he had read twice through the Bible and had started the study of Latin. Between 1780 and 1786 he attended two boarding schools, where he learned elementary mathematics and gained a reading knowledge of Latin, Greek, French, and Italian. He also had begun independent study of natural history, natural philosophy, and fluxions, and had learned to make telescopes and microscopes. In 1786 Young began independent study of Hebrew, Chaldean, Syriac, Samaritan, Arabic, Persian, Turkish, and Ethiopic. Shortly thereafter he became tutor to his lifelong friend and biographer Hudson Gurney, who was a member of the Gurney banking family. By 1792 Young had become a proficient Greek and Latin scholar : had mastered the fluxionary calculus : and had read Newton's *Principia* and *Opticks,* Lavoisier's *Elements of Chemistry,* Joseph Black's manuscript lectures on chemistry, and Boerhaave's *Methoclus studii medici,* in addition to plays, law, and politics.

Between 1792 and 1799 Young studied medicine at London, Edinburgh, and Göttingen (M.D. 1796). In January 1794 he was one of the assistants in experiments of the Society for Philosophical Experiments and Conversations organized by the chemist Bryan Higgins.[2] At the end of 1794 and in 1795, when he was at Edinburgh, Young began to enjoy music, dancing, and the theater, and in general to abandon the practices of the Society of Friends. Later in his life he formally became a member of the Church of England. In 1797-1803 he was enrolled at Emmanuel College, Cambridge (M.B. 1803 : M.D. 1808), partly to fulfill the requirements of the Royal College of Physicians and partly to satisfy the desires of his maternal uncle, Dr. Richard Brocklesby, who sponsored Young's medical education and his election to the Royal Society (19 June 1794). Brocklesby also introduced Young to such influential men as Edmund Burke, the duke of Richmond, and William Herschel. When Brocklesby died in 1797, he left Young his London house, his library and paintings, and £10,000.

Young moved from Cambridge to London in 1800 and attempted to establish a medical practice. He was never very successful as a doctor, however, probably because he did not inspire confidence in his patients. Young's undemanding practice gave him the opportunity for regular attendance at meetings of the Royal Society. As a result he became known to the Society's president, Joseph Banks, and to Benjamin Thompson, Count Rumford, founder of the Royal Institution.

In the summer of 1801 Rumford was looking for a professor of natural philosophy. On Banks's and Rumford's recommendations, Young was employed on 3 August 1801 as "Professor of Natural Philosophy, Editor of the Journals, and Superintendent of the House" at an annual salary of £300. As professor his first task was to prepare popular lectures on natural philosophy and the mechanical arts for the Institution's members. Young delivered these lectures in 1802 and 1803, and published them in revised form in 1807.[3]These lectures were erudite and at times contained the results of his recent researches. They also were obscure, technical, and too detailed for a popular audience. At the same time, in contrast, his colleague Humphry Davy's lectures on chemistry were brilliantly successful. Rumford left England in May 1802, and Young seems to have become unpopular with the Institution's managers. They probably forced his resignation, which was effective 4 July 1803.

Young then resumed his medical practice in London and later. during the summers, in the fashionable resort of Worthing. On 4 June 1804 he married Eliza Maxwell, who was related to the Scottish aristocracy through the family of Sir William Maxwell of Calderwood.

In November 1808 Young gave the endowed Croonian lecture to the Royal Society and he was elected ot the Royal College of Physicians in December 1809. During that winter at the Middlesex Hospital, he delivered a course of lectures on physiology, chemistry, nosology and general practice, and materia medica that were published in 1813. In Janunary 1811 Young at last obtained a lifetime professional position, being elected physician to St. George's Hospital. He was chosen to give the other endowed Croonian lecture, to the Royal College of Physicians, in 1822-1823; and in March 1824 he was appointed inspector of calculations and physician to the Palladium Insurance Company, at an annual salary of £500.[4]

During much of his life Young received a substantial income as an anonymous author of a wide variety of articles. In 1808 and 1809 he wrote for *Retrospect of Philosophical, Mechanical, Chemical, and Agricultural Discoveries;* in 1810, an article for the *London Review;* between 1809 and 1818, at least twenty–one articles for the *Quarterly Review;* and between 1816 and 1824, over sixty articles for the *Supplement* to the *Encyclopaedia Britannica*. These last works included biographies as well as many pieces on optics, mechanics, and the mechanical arts,[5]

Young held several public offices related to science. From 22 March 1804 until his death he was foreign secretary of the Royal Society, and after 1806 he was also a member of its Council.[6] He was at times a consultant to the Admiralty and was secretary of the Royal Commission on Weights and Measures from 1816 to 1821. Young was secretary of the Board of Longitude at an annual salary of£300 from 1818 until its abolition in 1828. He was also superintendent of the *Nautical Almanac,* at an additional salary of £100, from 1818 until his death. The last two posts were among the very few salaried scientific offices in England; and with Young's appointment to them, his combined income became commensurate with his social status. In 1827 Young's work in science received international recognition when he was elected a foreign associate of the French Academy of Sciences

Young was a scholar with the scholar's love of knowledge and the search for truth, however esoteric. Shortly before his death he persisted, against advice, in compiling his Egyptian dictionary and expressed great satisfaction that he had not yet spent an idle day in his life.[7] His self–education in many difficult fields shows that Young had the successful autodidact's persistence and self–confidence. He never seems, however, to have developed much sensitivity, in his professional relations, to other people's emotions, or differing perspectives. In his professional life he seems to have been formal almost to coldness and self–assured almost to being cocksure. Young's writing was frequently both prolix and obscure; at other times it was concise almost to incomprehensibility. Despite these limitations, as his varied career continued to open new vistas of scholarship, his education and independent income gave him the opportunity to be an intellectual dilettante.

As a result of his uncle's influnence and his mariage, Young's social position was high. He was fond of music, dancing, riding, and conversation and he valued and sought friendship and acquaintance with persons of cultire and social status. After abandoning his Quakerism he seems to have been impeccably conservative at a time when he English establishment was reaching conservatively; to threats of radicalism at home and abroad. In sum, Young had the attitudes, personality, ability money, and influence to be a gentleman scholar and to pursue careers as a physician, writer, administrator of science. and Egyptologist as well as a nautural philosopher. Consequently his diverse writings are related to each other more by his love of scholarship and the accidents of his life than by any dominant research or theoretical concerns. But, unlike most gentlemen scholars. Young was exceptionally intelligent. As a result he often showed clear insight into problems and made several important discoveries.[8]

Young once remarked that, as a natural philosopher, "…actute suggestion was … always more in the line of my ambition than experimental illustration"[9] In the course of his very diverse writings Young did make many "acute suggestion," as well as many ingenious "experimental illustrations," in physiological optics, the theory of light, mechanics, and Egyptian, linguistics. In none of these fields, however, did he systematically develop his discoveries, hypotheses, or suggestions, Nor did he fully confront their implications. His failure to do this, despite the importance of some of his discoveries, partly accounts, for his limited influence in science.

From 1791 to 1801 Young published most of his experiments and theories in physiological optics. In 1793, when he wrote his first important paper, "Observations on Vision," there wasno consensus about the the mechanism of the accommodation of hte eye. Various earlier authors had argued that the eye adjsted its focus to different distances by changing either its length or the curvature of the cornea or the crystalline lens. Young conjectured that the lens is composed of muscle fibers. Nerve impulses are sent "… by the ciliary processes to the muscle of the crystalline [lens], which by the contraction of its fibers becomes more convex…"[10] Measuerments that he had made on the lens from an ox's eye indicated that the necessary change in focl length could easily be achieved by the possible changes in the shape of the lens.[11] In 1796 in his doctoral dissertation, Young temporarily abandoned this hypothesis when he learned of investigations by Everard Home, John Hunter, and Jesse Ramsden that appeared to show that accommodation was achieved by changes in the curvature of the cornea and the length of the eyeball.[12] These researchers als had reported that persons who and had their len' removed retained the ability to change the of their eyes.

Late in 1800, however, Young reaffirmed his first hypoth; after performing new experiments that refute Home and Ramsden. In his paper "On the Mechianism of the Eye," he first derived a formula for he path of a ray refracted through a variable medium such as the crystalline lens.[13] Then he described his improvement of the optometer, analyzed the optics its dimensions, and computed the change in focal length that would be required to accommodate for near and far vision.[14] Next Young determined the amount of change that would have to occur in the eyeball, singly or jointly for accommodation.[15] Then he made a series of observations that were senstive enough to detect as little as one–fourth of the required change in hte cornea. He found no change.[16] His most compelling experimental demonstration, however, involved immersing his eye in water, which eliminated refraction at the cornea. His power of accommodation was unchanged. This result eliminated any role for the cornea in accommodation.[17] Furthermore, Young couls perceive no change in his ability to accommodate even when he made the length of his eye almost invariable by rotating it to the side and applying pressure.[18] Finally he reported that he had examined five persons without crysalline lenses. None of them had any power of accommodation[19].

To shoe that change in hte shape of the lens do take place, Young made use of his own astigmatism. By viewing an out–of–fous pint he first produced a "Star" image on his retina; then when he passed light form the point through horizonal or vertical slits, he observed straight–sided bands with a relaxed eye and curved bands when he accoummodated. From thsi he concluded that the only way such curvature could be produced was by az change in hte shape of the lens during accommodation. Young then formally readopted his opinion of 1793 that the lens chagnged shape because it was a muscle. His final conclusion was "… whether we call the lens a muscle or not it seems demonstrable that such a chnage of figure takes place [in it] as can be produced by no external cause."[20] In this paper young clearly demonstrated design and per form selicate experiments and draw convincing conclisions that did no go beyond his evidence. Moreover he was able to refute the opinions of persons reowned as Home.

In 1801 Young also suggested that the retina responded to all colors in terms of variable amounts of three "priuncipal colours," He believed that "… it is probable that the motion of the retina is rather of a vibratory than an undulatory nature…" "Now as it is almost impossible to conceive each sensitive point of the retina to contain an infinite number of particles, each capable of vibrating in consonance with every possible undulation, it becomes necessary to suppose the number limited, for instance, to the three principal colours, red, yellow, and blue…"[21] In 1807 he reaffirmed this hypothesis but eliminated any reference to undulatory theories:

It is certain that the perfect sensations of yellow and blue are produced respectively by mixtures of red green and of green and violet light, and there is reason to suspect that those sensations are always compounded of the separate sensations combined; at least, this supposition simplifies the theory of colours; it may, thereofre, be adopted with advantage, until it is found to be inconsistent with any of the phenomena…"[22]

Part of Young' "reason to suspect" presumably was based on John Dalton's blindness to red. Dalton thought it "… probable that [his] vitreous humour is of a deep blue tinge; but this has not been observed by anatomists, and it is much more simple to suppose the absence or paralysis of those fibres of the retina which are calculated to perceive red…"[23] Young published nothing more than these "acute suggestions" on tricolor vision. Max well well and Helmholtz later modified and extended his speculations into what has come to be called the Young–Helmholtz theory of color sensation.[24]

Young's most sustained interest in natural philosophy was his attempt to gain aceptance for an undulatory theory of light. His failure was partly the reasult of everal hostile reviews of his first papers by Henry Brougham and [artly the result of the inherent limitations of his work.[25] Young never worked out a detailed mathematical theory; nor were his suggestions, except possibly for hte princilpe Augustin Fresnel, Young's colleagues, how ever quickly acknowledged the principle of interference as a major discovery.

Young's interest in the nature of light probably began with his investigations on the formation of the human voice for his Göttingen dissertation and lecture. During the three years after his return to from Göttingen he wrote an essay on the wrote an essay on the human voice. This led him to make theoretical and experimental investigations of vibrating strings, musical pipes, beats, and the motions of fluid.[26] During this work he was "forcibly impressed" with the probability of a very close "analogy" between the vibrations of a series of organ pipes and the colors of thin plates. This analogy was later dismissed by his biographer George Peacock as "fanciful and altogether unfounded" , but it seems at least to have impressed Young with the need to reexamine the accepted theory of the nature of light.[27]

For many years before 1800, when Young published his first discussion of the nature of light, most men of science had affirmed that light is particulate. Newton had argued that if light were a vibration in a material medium, it ought to bend around corners; and the vibrations would have to have "sides" to account for polarization. Finally, Newton's arguments that the pypothetical Cartesian interplanetary vortices would cause the planets to spiral into the sun seemed to apply with equal force to an interplanetary ether.[28]In part Newton was also writing against the opinions of Descartes that light was a "pression" in a fluid and the ideas of Hooke and Huygens that light was a random succession of pulses in a Cartesian plenum. During the middle of the eighteenth century Euler had argued that there was a strong analogy between light and sound, and that light must therefore be a vibratory motion.[29]In 1792 Abraham Bennet suggested to the Royal Society that light must be caused by vibrations in "the universally diffused caloric or matter of heat or fluid of light."[30]Neither Euler nor Bennet attracted any large, following presumably because the same conclusive objections seemed to apply to their particular hypotheses that had to Descartes's Hooke's and Huygens'. In contrast, the emission theory did not seem to be plagued by similar difficulties. In fact, in 1796 and 1797 Brougham had shown how the emission theory could be extended to account for "inflection" and dispersion.[31]

In January 1800, in a paper he submitted to the Royal Society, Young reopened this old debate. He began by stating that "… some considerations may be brought forwards, which may tend to diminish the weight of objections to a theory similar to the Huygenian. There are also one or two difficulties in the Newtonian system, which have been little observed,"[32] The difficulties were not new; light has a uniform velocity regardless of its origin; light is partially reflected from every refracting surface. In turn, one of the prime, "objections" to the vibratory system was that it was founded on the supposed existence of some kind of "luminous ether" Young answered this objection by arguing that "… a medium resembling, in many properties, that which has been denominated ether, does really exist, is undeniably proved by the phaenomena of electricity…"[33] Because the existence of the "electric medium" was manifest, Young argued, it was legitimate to assume the existence of an analogous medium for the transmission of light. He then went on to assume that, except for its medium and frequency, the undulations of light are the same as those of sound. Making these assumptions, Young was then able to "solve" the problems of the uniform motion of light that seemed to plague the emission system because "… all impressions are known to be transmitted through an elastic fluid with the same velocity."[34].

Earlier in this paper Young had shown that sound waves had very little tendency to diverge. Hence, he argued, ". in a medium so highly elastic as the luminous ether must be supposed to be, the tendency [for light] to diverge must be infinitely small, and the grand objection to the system of vibration will be removed."[35] By assuming that "all refracting media" contain the same mechanical ether composed of elastic particles of matter, but with different densities of ether of the same "elasticity," he then gave qualitative explanations of "…partial and total reflection refraction, and inflection [diffraction],"[36] He concluded this discussion by asserting that the "colours of light consist in the different frequencies of vibration of the luminous ether…" He based this statement on his supposed analogy between the sounds of organ pipes and the colors of thin plates.[37]There were no published scientific reactions to this article, perhaps because Young's arguments seemed familiar, speculative, and unsupported by any new experiments.

In May 1801 Young discovered his principle of interference "… by reflecting on the beautiful experiments of Newton…"[38] By November he had completed what became his second Bakerian lecture, "On the Theory of Light and Colours," in which he partially announced this principle.[39] His statement, however, was entirely hypothetical and not at all experimental; "When two Undulations, from different Origins, coincide either perfectly or very nearly in Direction, their joint effect is a Combination of the Motions belonging to each."[40] He then went on to report an experiment that exhibited four orders of fringes produced by sunlight reflected from a set of parallel grooves in glass.[41] Using Newton's measurements of the spacing of ring colors and the principle of interfernce Young calcutated the waverlengths and frequencies of the visible spectrum and gave qualitative explanations of the colors of thin and thick plates, of color or blackness associated with total internal reflection, and of the colors produced by inflection.[42] On the basis of these reasonings he concluded; ":Radiant Light consists in Undulations of the luminiferous Ether."[43].

In July 1802 Young made the first full an nouncement of his principle of inerference; "… whenever two portions of hte same light arrive at the eye by different routes, either exactly or very nearly in the same direction, the light becomes most intense when the difference of the routes is any multiple of a certain length, and least intense in the intermediate state of the interfering portions;and this length is different for light of different colours."[44] He then used the principle to explain the fringes produced by thin fibers and the "colours of mixed plates." In the case of the fibers, Young argued that the fringes were caused by the interference of one portion of light reflected from the fiberence of one portion of light reflected from the fiber with another "…bending around its opposite side…"[45] He then calculated the difference in path lengths for the two portions of red light that produced the first fringe. his measurements were crude, and his result was only within 11 percent of what he had expected on the basis of Newton's data.

Nonetheless, Young concluded that "…this coincidence, with only an error of one–ninth of so minute a quantity [is] sufficiently perfect to warrant completely the explanation of the phenomenon, and even to render a repetition of the experiment unnecessary…"[46]Young was easily persuaded. He used the same "bending" explanation to account for the halos that can be seen when wool is held to the light and also for "… coloured atmospherical halos…"[47]Young's suggestions about fringes appear to have been unknown to Fresnel, who, in 1818 or 1819, was the first to work out a physically and mathematically datifactory explanation for the fringes that did not depend on the implausible (and nonexistent) reflecting and bending of rays[48].

In this same paper Young's discussion of the colors or mixed plates is more persuasive than his discussion of fibers. First he showed that the diameter of the colored circles was inversely depedent on the "refracitve density" of the interposed liquids. Next he asserted that this and other experiments necessarily implied that if light is an undulation, then its velocity increases an the medium becomes denser. Young then attempted to describe an experiment that would decide between the two theories. Although the results he obtained from this experiment were equivocal, he asserted that they confirmed his prediction[49].

Young presented his first really convincing evidence that fringes are produced by interference in his third Bakerian lecture, "Experiments and Calculations Relative Physical to Optics" (Novermber 1803). First he exposed a small piece of paper to sunlight diverging from a pinhole. The shadow exhibited not only fringes of color, but "… the shadow itself was divided by similar parallel fringes…" Then, by inserting a small screen into either edge of the shadow he was able to make the fringes disapperar, "… although to retain its course…[Hence]these fringes were the joint effects of hte portions of lihgt passing on each side of hte slip of card and inflected… into the shadow."[50] In the next section of hte paper Young compare the fifferent "Characteristic lengths" (wavelengths) that were implie by Newton's ob servations of friengs produced by knife edges and by a hair, and in his own similar experiments with the "analogous interval, deduced form the experiments of Newton on thin plates" These relsults were within about 13 percent of each other. Young optimistically concluded that "this appears to be a coincidence fully sufficient to authorise us to attribute these two classes of phenomena to the same cause."[51].

Young did not stop after presenting his evidence and conclusions. Rahter he applied his "principle" to the explanation of supernumerary rainbows to the colors of natural bodies and to an "Argumentative Inference respecting the Nature of Light."[52] Young's argument was that because the lengthes and phenomena in his experiments on interference and in hte colors of thin plates described by Newton were similar, they were the same phenomenon; interference. Newton's experiments showed that hte denser the meidum, hte smaller the intervals but, according to the emission the ory, they ought to be larger. Therefore light must move more slowly in hte denser medium, which was contrary to the assumption made to explain refraction on the emission theory. Therefore light must be an undulauion in the "luminous ether."[53].

Young summarized and completer this phase of work on his undulartory theory by 1807 for the published version of his lectures for the Royal Institution. To the published version he added a description of his two–slit experimental demonstration of interfernece. He also withdrew his speculation that the colors of halos were produced by interference.[54] At this time Young had convingly demonstrated the fact of hte interference of light but he had by no means deminstrated that light was the longitudinal undulation of a mechanical, luminiferous ether.

By early 1810 Young had learned of Malu's discovery that in addition to its being polarized by transmission through Iceland spar, light could be polarized by reflection.[55] This implied that lihgt could acquire "… properties independent of its direction… but exvlusively relative to the sides of the … ray…"[56] Young concluded that "the general tenor of these phenomena is such, as obvioulsy teor of these phensomena is such as obsviously to point to some property resembling polarity which appears to be much more easily reconclieable with the Newtonian ideas than with the Newtonian ideas than with those iof Huygens."[57] Between 1811 and the early 1820's Arago Biot, and Brewster had made many additional discoveries indicating that light must have more property very much like "sides" or "polies"[58] In Januraty 1817 Young suggested to Arago that polatrization might be accounted for by assuming that it was mintute transverse component added to the longitidinal undulation of the ether that he asumed to be light. "But its inconceivable minuteness suggests a doubt as to the possibility of its producing any sensible effects; in a physical sense it is almost an evanescent quantity, although not in a mathematical one"[59].

By September 1817 when he wrote his article "Chromatics" for the *Supplement* to the *Encyclopaedia Britannica* Young had worked out a qualitative suggestion of how a small tranverse component of vibration might explain the facts of paratial refelection. He was not confident that it did, how ever, not did he expres any idea that the felt willing to suggest was "… a mathematical postylate, in hte undulatory theory without attempting to demonstrate its physical foundation that a transverse motion might be propagated in a direct line…" Rather then urge that this modification was true, Young was careful to emphasize the minuteness of this transverse component. As far as the dicovery of the true theory of light was concerned, he continued to belive at this time that "… the general phenomena of polarisation. cannot be said to have been explained on any hy pothesis respecting the nature of light."[60] Young' theory at thsi time also did not adequatelly predict the seacing of hte exterior fringes of diffraction or the rectilinear propagation of light. Less than a year later Fresnel had complected a mathematical solution to both problems.

In July 1818 Frensel reported his solution to the problem of explaning the exterior fringes. In it he demonstrate thier production by a combination of the principles of interference and Huygen's principle that a wave front may be considered to consist of an infinite number of point sources of new waves. Fresnel calculated thier combined effect by means of hte integral calculus ; and in passing he also derived a solution to the problem of hte rectilinear propagation of light, which had been Newton's chief objection ti an undulatory theory Frencal also desighed and performed interence experiments to test his theory. The difference between the observed adn calculated positions of hte successive minima were never greather than 0.05 millimeter, or 7.4 percent and they averaged about 0.006 millimeter or about 0.9 percent. Probably independently of any knowledge of Young work or any use if transerse undulations, Fresnal had given a far more persuasive argument than had Young lihgt was an undulation[61].

As early as 1816, and before Young made his suggestion, Fresnel seems to have become convinced that polarization might be explained by some kind of transverse undulation.[62] From then until his death in 1827 he applied this assumption successfully to a detailed mathematical analysis of most known optical phenomeana,; refleectionn diffraction, partial reflection single and double refraction, and polarization. Only in hte cases of dispersion, elliptical polarization by reflection from metals, and absorption did he fail to derive explanatuions and founds the presictions of which were repeatedlly confirmed by experiments. What young had been unable to do, even concepetually, Fresnel did mathematically and experimentally – and probably with litte or no assistance from Young' suggestions. Young claimed the priority of suggestion, and Fresnel agreed;but Fresenel disagreed with young's contention that he had planted the tree and Fresnel had picked the apples; "I am pesonal Ly convinced that the apple would have appeared without the tree for hte first explanations which occurred to me of the phenomena of hte coloured rigns or of the laws of reflection and refraction, I have drawn from my own resources without havings read either [Young's] work or that of Huygens."[63] Nor ws Frensnel plagued by doubt that light wws indeed the transverse undulations of an elastic soild ether. In contrast, Young realized that if there were to be transevrse undrlations the undulating particles had to have lateral adhesion, But he concluded in 1823, if they did "… it might be inferred that the luminiferous ether, pervading all space adn penterating almsot all substances is not only highly elastic, but absolutely solid!!!"[64].

Young' hesitation to affirm the existence of transverse undulatiuons which were now essential for the success of any undulatory theory, depended on his sense of hte physical requirement they imposed on the ether. At this time there was no alternative to a mechanical ether Young then abandoned his work on light and returned to some of his older lines of research at least in part because he had been unable to reduce the theory if light to propositions inn mechanics.

In these investigations onb lights Young basec his bypotheses on phsical analogies or comprehensible physical entities such as mechanical ethers and imponderable fluids. If such a hypothesis led to a plausible qualitaive or semi–quantitaive explanations, he was quick to make rather extraagant claims that his explations were true. He had mathematuical ingenuity; but he had taught himself fluxions and he lacked skill in hte use of differetial annd integral calulus. His discovery of interference conviced him that light must be at least perodic and [rbably an unducltion; but his convction that there must be some mechanical enity to unadulate brought him to an impasse, for he was convinceed that a mechancial lumififerous had contradictory physical properties. Ironically Young' faith in the use of mecahanical analogies, which had led him to his dicoveries, kept him form accepting thier consequences. Perhaps this was because he lacked Frenel's skill and faith in mathematics. Fresnel either solved or ignored the problems that chackmated Young. His skillful so community that Young never persuaded. Young work in mechanics had limited influence for some of these same reasons.

Young described many of his mechaincal discoeries and "suggestions" in his first book *A Course of Lectures of Natural Philosophy and the Mechanical Arts* Its organization is typical of numberous popular "courses," "systems," and "syllabi" that were published frequently in eighteenth-century Britain. In it young juxtaposed lectures on motion, forces, and "passive strength" with ones on drawing writing modeling and engraving; lectures on hydrostatics, hydraulics, and the friction of fluids with ones on hydeaulic and pneumatic machnines such as pumps steam engines and firearms; and lectures on astronomy hte physics of matter, electricity and magnetisn, with ones on the study of meteors vagetation, and animals.

Unlike those of the typical "course" however Young's arguments and illstrations were much less easy to understand and his scholarship intimidating, Moreover, the size of the work– two thick quarto volumes totaling more than 1,500 closely printed pages–made it a work of reference for a few persons rather than a popular text for many Indeed, much of the second volume is devoted to a long index and to an annoted bibliography of about twenty thousand reference on all the subjects in his lectures, as well as reprints of several iof his papers. Anyone who had the patience and time to explore Young's *Course* might have found several "acute siggestions." At this time however,several relativety new scientific journals had begun to supplant books as means to announce discoveries that were not presented to the philosophical societies[65].

In his lecture "On Collision," Young was probably the first person to suggest substituting the term "energy" for "living force" or *vis viva* His use of the term, however, indicates that he did not generalize this concept. Rather, he used it only twice for what is now known as kinetic energy. As he stated it; "The term energy may be applied, with great propriety, to the Product of the mass or weight of a body, into the square of the number expressing its velocity."[66] The word "energy" did not become widely used until after its revival in the early 1850's by Rabkine and William Thomosn in their writings on hte conservation of energy[67].

Young defined a "modulus of elasticity" in his lecture "Passive Streaght and Friction." It is a;most impossoibly obscure: "… we may express the elasticity of any substance by hte weight of a certain column of the same substance which may be denominated the modulus of its elasticity and of which the weight is wuch that any addition to it would increase it in the same proportion as the weight added would shorten by ots pressure, a portion of hte substance of equal diameter."[68] In 1867 Thomson adn Tait reexpressed this modulus un its present form; hte ratio between the stressing force and the resultant strain. They also pointed out that this is an additional modulus of rigidity or shear modulus that is not the same as Young's.[69].

In his *Lectures* Young also began developing his theory of hte tides. His first dictussion outlined how an analogy to a pendulum might be used to develop such a theory.[70] By 1811 he had completed its mathematical development; and he finally published it, anaonymously, in 1813. His analysis used fluxions and was based on another analogy to a pendulaum.The vibrating pendulum also had a vibrating suspension point and it experienced resistance proportional to the first and second powers of the velocity.In this way young attempted to account for the effects of friction on the times of the tides.[71] In 1824 he published his complete theory in the *supplement* to the *Encylopaedia Britannica*.[72] His theory was probably the most complete when it was published, but it was soon superseded by the work of Airy, which was published in 1842.[73] Airy appears not to have read any of Young's writing on the tides.[74].

As a result of his work on the tides and on the Commission in Weight and Measures, Young had a continuing interest in hte pendulum. As secretary to the Commission, he wrote its report, which recommended that the standered of length be a "pendulum vibrating seconds of mean solar time in london, on the level of hte sea, and in a vacuum"[75] Later he published articles on efforts affecting this standard on reduction of pendulum lenghts to sea level.[76].

After he his work on hte theory of light Young returened to his long–standiong interest in languages.[77] In 1813 he had started his attempts to decipher the Egyption hieroglyphics, and by the following year he had translated the "enchorial" or demotic running script of the Rosetta Stone and had conclded that hte enchorial was derived from the hieroglyohic. He published very littel at this time and most of what did appear was published very little at this time and most of what did appear was publised anonymously. During 1817 and 1818 Young retured to the subject in preparing his unsigned article "Egypt" for the *Supplement* to the *Britannica* This article was published was in December 1819. His other commitments for the *Britannica* as well as the demands of his *Nautical Almanac,* seem to have prevented Young from doing much more on hieroglyphics than corresponding with other translators. In March 1823 he published, under his own name, a comparison of his and J.F. Champollion's alphabets, intending to assert his own priority. His final work was *Enchorial Egyptian Dictionatry,* published in 1830.

Young' need to defent his priority as a translator of hieroglyphics, as well as is limited influence in natural philosophy (quit apart from the techncal limitations of his work), were the result of his personality, his methods of communication, and his career. He left his "acute suggestions" for others to develop and complete. He published sporadically; often anonymously; frequently in obscure, unwieldy, or unlikely publications; and almost always using weak analogies, awkward prose, or inadequate mathematics. Young's frequent changes of occuption prevented sustained concentration and favored dilettantism.

Late in his life, when he added the demands of two salaried scientific posts to his other activities, his principal avocation had become hieroglyphics. Young was a sporadically brilliant, gentleman natural philosopher who lived to se other men receive the credit and fame for completing what he had begun.

NOTES

1. Biographical details of Young's life are drawn from the accounts of François Argo, Hudson Gurney, George Peacock. Thomas Pettigrew, and Alexander Wood. Also see H. S. Rovell, "Thomas Young and Gottingen."

2. J. R. Partingtom *History of Chemistry* 111, 728–729.

3.*The Archives of hte Royal institution of great Britain in Facsimile,* II and III, *Passim* MY account of Young's career at the Royal Institution is based on G. N. Cantor, "Thomas Young's Lectures at the Royal Institution," Also see Morriss Beraman, "The Early Years of the Royal Institution 1799-1810; A re–evalution" and Henry Bence Jones *The Royal Institution* 188–257.

4. William Munk,*The Roll of the Royal College iof physicaians of London* 111, 80–88; and *works of sir Benjamin Collins Brodie* 1,90–93.

5. Young's anonymous published are listed are listed in Hudson Gurney, *Memoir of the Life of Thomas Young* 51–62. Hill Shine and Helen shine, in *The Quarterly Review Under Gifford,* list a few other articles that may be by Young, *Passim.*

6.*Record of hte Royal Socuety of London* (1897) 208, and Sir Henry Lyons *The Royal Society 1660-1940,* 220, 223, 227, 243, 245.

7. Gurney *op. cit.,* 42.

8. G. N. Contor's articles on Young have been very influential on my thinking, but I alone am responsible for his interpretation of young's personality.

9. George Peacocok, *Life of Thomas Young,* p. 397.

10. Young, "Observations on vision," *Works* 1,5.

11.*ibid.,* 6.

12. Everard Home, "On the Mechanism Employed in Producting Muscular Motion," 1.

13. Young,*works* 1,20–21.

14.*ibid.,* 21–36.

15.*ibid.,*37.

16.*ibid.,*37–40.

17.*ibid.,* 41.

18.*ibid.,* 41–43.

19.*ibid.,* 46–48.

20.*ibid.,* 51.

21. "On the theoruy of light and Colours," *ibid.* 146,147, "I use the word unulation in preference to vibration because vibration is generally uhderdtood as implying a motion which is continued alternatly backwards and fpr wards by a combiation of hte mometum if the body with an accelerating fprce and which is naturaly more or lesss permament but an undulation is supposed to consist in a vibratory motion except in consequence of the transmission of succseeding undulations of a distiant vibrating body; as in the air the vibrations of a chord produce the undulations constituting sound" [p. 143].

22.*A Course of Lectures on Natural philosophy and the Mechaniacal Arts,* 1,439.

23.*ibid.,* 11,315

24. Alexander Wood, *Thomas Young, Natural Philiospher 1773-1829*.113. Also see James p. C. Southall, ed., *Helmholrt's treatise on Physological Optics* 11. 143–146.

25. For a distrion of Broughtam's reviews, see the traditional accounts by Peacock and Wood in their biographies of Young. Their interpretation has recently been challenged by G. N. Cantor, "Henry Brougham and the scottish Methodological Traditon;" and Edgar W. Morse, "Natural philsophy, Hypotheses, and Impiety," ch. 2.

26. Peacock *op. cit.,* 90–91; Andrew Dalzel, *History of the university of Edinburgh* 1,144, 161; Young, *works* 1,199.

27. Young, *Works,* 1.199,81,81n.

28. Isaac Newton, *Otpicks* 362–370 (query 28). Also see A. W. Badecock, "Physical Optics at the Royal Society, 1660-1800." Badcock's article should be compared with the interpretaion in Henry Steffens, "The Developement of Newtoian Optics in England, 1738-1831," Steffens' thesis is one of the first systematic reinterpretations of the history of eighteenth–centruy optics. His conclusions are similar to mine.

29. Sir Edmund Whittaker, *A History of hte Theories of Aether and Electricity,* 1,*The classical Theories* 97–98.

30. Quoted in Badcock, *op. cit.,* 102.

31. Heny Brougham, "experiments and Observations on the Inflections, Reflection, and Colours of Lights" ; and "Further Experiments and Observations on the Affections and Properties of Light."

32. "Outlines of Experiments adn Inquiries Respecting Sound and Light," *Works* I,79.

33.*Ibid*.

34.*Ibid*.

35.*Ibid*.,78–79.

36.*Ibid*.,80.

37.*Ibid*.,81.

38. "A Reply to the Animadversions of the Edinburgh Reviewers…" in *Works* 1,202.

39.*Works,* 1,140–169.

40.*Ibid*.,p. 157. Original in italics.

41.*Ibid*.,159.

42.*Ibid*.,160–166.

43.*Ibid*.,166.

44. "An Account of Some Cases of the Production of Colours not Hitherto Described," *Ibid* 170.

45.*Ibid*.,171.

46.*Ibid*.,171–172.

47.*Ibid*.,172–173. Young later designed an instrument, which he called an eriometer, that used these interference halos as a measure of the average size of hte fibers in wool or particles suspended in a fluid. See Young, *works* 1.343, 172,305.

48. Augustin Fresnel "Mémoire sur la diffraction de la lumière," 282–364. Also see A. Rubinowica, "Thomas Young," which gives a different interpretation of Young's explanation. On the colors of the haols see carl Boyer, *The Rainbow,* esp. 245–246. These halos are caused by refraction in ice crystals. The slammer halo was first explained by Mariotte in 1679 and the larger by Henry Cavendish in a conversation with Youg. See Young, *Course of Lectures*1,443–444.

49. Young,*works* 1,174–175.

50.*Ibid.,*180.

51.*Ibid.,* 181–184.

52. Supernumerary rainbows are the result of interference effects; the colors of natural bodies are not. See Boyer *op cit, Passim* for a discussion if supernumerary rainbows.

53. Young, *works,*1,187–188.

54. Young, *course of Lectures,* 1,457–471,443–444.

55. Young, *Works,* 1,247–254.

56. “Popular Statement of the Beautiful Experiments of Malus…” 345.

57. Young,*works,* 1,251.

58. Alexander Wood, *Thomas Young* 181–183. Also see Morse, *loc, cit*.

59. Young, *works,*1,383.

60.*Ibid.,*332–334.

61. Augustin Fresnel, “Mémoire sur la diffraction de la lumière,” 262–335.

62. Fresnel, “Mémoire sur i’influence de la polarisation,” 394n.

63. Young,*works,* I,401–402. Translation in Alexander wood, *Thomas Young,*199.

64. Young,*works,* I,415.

65. S. Liley. “Nicholson’s Journal’(1792-1813),” Also see David M. Knight *Natural Science Books in English 1600-1900* esp.ch.11.

66. Young, *Course of Lectures,* I,78.

67. The term used Helmholtz and the other “discovers” of the conservation of energy had been “Conservation of force,” Young’s work seems to have been rooted in the *visviva* controversies of the eighteenth century. Also see D. S. L. Cardwell, “Early Development of the Concepts if power Work, and Energy.”

68. Young, *course of Lectures,* I,137. Also see Young, *works,* II,129.

69. W. Thomson and P. G.Tait, *Natural philosophy,* secs 686, 687; W. Thomson, “Elasticity,” Secs 41,42, Also see the discussion bu Isaac Todhunter in *History of the Theory of Elasticity,* I,82–83.

70. Young, *Course of Lectures* I,583–588. His Prinicipal in novation in the *Lectures* was to devise a map of the times of simultaneous high water around the Brithsh Isles (I.pl. 38., fig, 21) He did not, however, discuss this concept or its potential for generalization. The term “cotidal map” now used was coined in 1833 bu whewell: “Essay Towards… a Map of Co–tidal Lines.”

71. Young, *Works,* II.262–290.

72.*Ibid.,* 291–335.

73. “Tides and Waves,” in *Encyc;lopadedia metropolitana* (1842).

74. Young, *works,* II.262n.

75.*Supplement* to the *Encyclopaedia Britannica* VI, 788.

76. Young, *Works,* II,8–28, 93–98; 99–101; *Quarterly Journal od Science Literature and the Arts,***22** (1827), 365–367.

77. Wood, *Thomas Young*, chs, 9, 10. Young, *Works*, III, is devoted almost entirely to his writings on languages. It also includes correspondence related to his controversies about priorities.

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