Two hundred years ago this month, Thomas Young presented his wave theory of light, which included the phenomenon of interference. Young presented his theory to fellows of the Royal Society in a lecture entitled “On the Theory of Light and Colours.” This article describes some of Young’s ideas about light, and the response they elicited from his contemporaries.

There is much that is unexpected in Young’s paper and in the reaction to it. For example, there was not a single equation. The word “interference” was barely used and the double slit was not mentioned. The work had limited influence at the time. Henry Brougham, who would later be Lord Chancellor, wrote shortly thereafter about Young: “We now dismiss, for the present, the feeble lucubrations of this author, in which we have searched without success for some traces of learning, acuteness, and ingenuity, that might compensate his evident deficiency in the powers of solid thinking, calm and patient investigation…”

Young was 28 years old in 1801, the year he presented the wave theory of light. A doctor of medicine, Young had become a fellow of the Royal Society in 1794 at the age of 21 for his work on vision. He was professor of natural philosophy at the Royal Institution from 1800 to 1803. His November 1801 talk was a Bakerian Lecture, part of an annual and endowed series that continues today. (Young had already given a Bakerian lecture, “On the Mechanism of the Eye,” in 1800.)

Young’s theory of light derived by analogy from his understanding of sound, and his belief that the two phenomena are similar except for the media of transmission. Sound is longitudinal waves in air and light is longitudinal waves in the luminiferous ether. The interference of light is analogous to acoustic beats.

Young’s work in wave theory and interference is largely encompassed by six publications, which are cited at the end of this article. In the first two,1,2 Young develops acoustic concepts and begins to apply them to optics. The third,3 “On the Theory of Light and Colours,” is all optics. The next two publications4,5 deal primarily with interference. The final one6 is largely a survey comparison of corpuscular and undulatory views of light.

The first publication, “Outline of Experiments and Inquiries Respecting Sound and Light,” was read to the Royal Society in 1800. Although it describes no experiments involving light, it does contain a five-page section, “On the Analogy Between Light and Sound,” that deals exclusively with light. Here, Young is troubled by the idea that corpuscles of light...
have the same speed regardless of their source and cause of emission. In one section, "On the Divergence of Sound," Young cites observations that waves do not necessarily spread out equally in all directions. He makes the same point about light in "On the Theory of Light and Colours."

The second publication, "A Letter Respecting Sound and Light," was published in August 1801. Young describes it as "a summary enumeration, to the principle positions which I have... endeavoured to establish." This paper focuses on acoustics, except for a single page about optics, presented in a peculiar way: A list of the properties of sound contains the item "Light is probably the undulation of an elastic medium." Under this heading are six succinct statements about light and one paragraph with a teaser: "The analogy which is here superficially indicated, will probably be made public more in detail..."

In this paper, Young discusses superposition in acoustics: "The particles of air may be jointly actuated by two or more sounds; and in this case, the several motions are to be added or subtracted, in order to find the actual joint motion."

The third paper, whose anniversary we recognize in this article, is "On the Theory of Light and Colours." It differs from the other papers in this group in length, structure, and in the viscosity of its prose. The paper is 36 pages long, about a quarter consisting of passages from Newton. It contains next to no mathematics. There are but four figures (Fig. 1). It is formally arranged, with hypotheses, propositions, corollaries, and scholia. Here are two excerpts from the introduction:

"The object of the recent dissertation is not so much to propose any opinions which are absolutely new, as to refer some theories, which have already been advanced, to their original inventors, to support them by additional evidence, and to apply to them a great number of diversified facts, which have hitherto been buried in obscurity."

"A more extensive examination of Newton's various writings has shown me, that he was in reality the first that suggested such a theory as I shall endeavour to maintain; that his own opinions varied less from this theory than is now almost universally supposed."

The headings of this work, which serve as outline and summary, appear on page 50.
**Headings of “On the Theory of Light and Colours”**

- **Hypothesis I** - A luminiferous Ether pervades the Universe, rare and elastic in a high degree.
- **Hypothesis II** - Undulations are excited in this ether whenever a body becomes luminous.
- **Hypothesis III** - Undulations are excited in this ether whenever a body becomes luminous.
- **Hypothesis IV** - The Sensation of different Colours depends on the different frequency of Vibrations, excited by Light in the Retina.
- **Hypothesis V** - A material Body has an Attraction for the ethereal Medium, by means of which it is accumulated with their Substance, and for a small Distance around them, in a State of greater Density, but not of greater Elasticity.
- **Proposition I** - All Impulses are propagated in a homogeneous elastic Medium with an equal Velocity.
- **Proposition II** - An Undulation conceived to originate from the Vibration of a single Particle, must expand through a homogeneous Medium in a spherical Form, but with different quantities of Motion in different Parts.
- **Proposition III** - A Portion of a spherical Undulation, admitted through an Aperture into a quiescent Medium, will proceed to be further propagated rectilinearly in concentric Superficies, terminating laterally by weak and irregular Portions of newly diverging Undulations.
- **Proposition IV** - When an Undulation arrives at a Surface which is the Limit of Mediums of different Densities, a partial Reflection takes place, proportionate in Force to the Difference of the Densities.
- **Corollary 1** - The same demonstrations prove the equality of the angles of reflectance and incidence.
- **Corollary 2** - It appears from experiments on the reflection of condensed air, that the ratio of difference of the sines varies simply as the density...
- **Proposition VI** - When an Undulation falls on the surface of a rarer Medium, so obliquely that it cannot be regularly refracted, it is totally reflected, at an Angle equal to that of its Incidence.
- **Corollary** - This phenomenon tends to prove the gradual increase and diminution of density at the surface terminating two mediums...
- **Proposition VII** - If equidistant Undulations be supposed to pass through a Medium, of which the Parts are susceptible of permanent Vibrations somewhat slower than the Undulations, their Velocity will be somewhat lesser by this Vibratory Tendency, and, in the same Medium, the more, as the Undulations are more frequent.
- **Corollary** - It was long an established opinion, that heat consists in vibrations of the particles of bodies, and is capable of being transmitted by undulations through an apparent vacuum.
- **Proposition VIII** - 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.
- **Corollary I** - Of the Colours of striated Surfaces.
- **Corollary II** - Of the Colours of thin Plates.
- **Corollary III** - Of the Colours of thick Plates.
- **Corollary IV** - Of Blackness.
- **Corollary V** - Of the Colours by Inflection.
- **Proposition IX** - Radiant Light consists in Undulations of the luminiferous Ether.

Young writes that the first three hypotheses are in agreement with Newton, which he demonstrates by quoting Newton extensively. The fourth hypothesis is Young's, and he is almost apologetic about this.

Hypothesis III stands apart in that it deals with human perception. This hypothesis was needed to connect physics and psychophysics since in 1801, color was seen but not recorded by spectrometer.

Proposition III addresses a key argument for the corpuscular theory. Newton wrote, “To me the fundamental supposition itself seems impossible; namely, that the waves or vibrations of any fluid can, like rays of light, be propagated in straight lines, without a continual and very extravagant spreading and bending every way into the quiescent medium... I mistake if there be not both experiment and demonstration to the contrary.” There is an acoustic equivalent to this discussion in the first paper.

Proposition VIII introduces interference, and its five corollaries provide specific examples of its manifestations. Yet the verb “interfere” is used but twice in this paper with no ado, and the word “interference” does not appear at all. These words would only become common in Young's subsequent writings.

In discussing the appearance of striated surfaces, first observed by Robert Boyle, Young comes so close to inventing the diffraction grating that it is hard to see how he missed.

In the fourth paper, “Production of Colours” (1802), interference is described by Young as “a simple and general law, capable of explaining a number of phenomena of coloured light.” Here, Young claims to have explained “all the phenomena described in the second and third books of Newton’s Optics.”

In the fifth publication, “Experiments and Calculations Relative to Physical Optics,” Young writes “… I have found so simple and demonstrative a proof of the general law of the interference of two portions of light... fringes of colours are produced by the interference of two portions of light...”

Young created interference fringes with a small hole in a shutter and “a slip of a card about a thirtieth of an inch in breadth.” He observed the fringes against the wall or another card. Young calculated the wavelengths of different colors and compared these calculations with those obtained with other arrangements.

Young describes an “Experiment on the Dark Rays of Ritter,” i.e., ultraviolet light, which had been discovered in 1801. Ultraviolet Newton’s rings were produced and recorded by an hour exposure of paper dipped in a solution of nitrate of silver. Young suggested that interference would be observable in the infrared with adequate thermometers.

The sixth publication derives from one of Young’s Royal Institution lectures. “On the Nature of Light and Colours” (1802-3) is predominantly a comparison between the corpuscular and undulatory views for a variety of phenomena, including the transmission of light through transparent media, “uniformity of velocity,” equality of angles of incidence and reflection, partial reflection, total internal reflection, combustion, stellar aberration, unusual refraction of the Iceland spar, dispersion by refraction, and diffraction. At the end, Young leaves the matter to experiment.
publication: "... the simplest case appears to be, when a beam of homogeneous light falls on a screen in which there are two very small holes or slits, which may be considered as centers of divergence, from whence the light is diffracted in every direction."

**Comments**

These writings share a number of interesting characteristics. First, none of the six papers contains a single equation. Indeed, some believe that Young was deficient in mathematics, although he did teach himself Newton's fluxionary calculus.

The discussion of interference is limited to the completely constructive and destructive cases. Intermediate situations are not discussed and there are no mathematical expressions for spatial distributions. There is some inkling of coherence, but no elaboration. Experiment descriptions include small apertures and expressions such as "... two portions of the same light ..." and "... derived from the same origin."

Young's technical vocabulary often differs from our own. He does not use the word "wave" in connection with light (although he does with water). For light and sound, Young uses the term "undulation." The Latin root is *undula*, meaning wave. Interestingly, Young distinguishes between undulations and vibrations.

Young seems to make no attempt to standardize his terminology. He does not select a term for "wavelength" but uses "interval" as well as a variety of expressions like "minuteness of its undulations" and "undulations of a given breadth." In one table, "length of an undulation" is used. The word "frequency" is used just as it is today and one table lists "number of undulations in a second" (expressed in millions of millions). For a "magnitude" there are several terms, e.g., "force of each undulation" and "quantities of motion." For "superposition" there are a number of expressions, for example: "joint motion," "uniting their motions;" "mutual action," and "united velocity."

Young was a sharp observer whose experiments were performed using simple apparatus.

Young's writings are sprinkled with conjectures that are impressively accurate. One is the continuity with the visible of the newly discovered infrared and ultraviolet. He anticipates nonlinearity in Proposition I and dispersion theory in Proposition VII. He proposes that striations produce some insect colors. He suggests a relationship between light and electricity.

Young was also wrong in places. He believed, for example, that waves carry no momentum.

**Young's influence**

Young's influence in his own era was less than we might expect given the importance of interference and the double slit in our current thinking.

One contributor was Young's style. According to a contemporary: "His language was correct, his utterance rapid, and his sentences, though without any affectation, never left unfinished; but his words were not those in familiar use, and the arrangement of his ideas seldom the same as those he conversed with. He was, therefore, worse calculated than any man I ever knew for the communication of knowledge... Nothing could show less judgment than the method he adopted; for he presumed... on the knowledge, and not on the ignorance of his listeners."

With his written comments, Young antagonized influential people. One was Henry Brougham. As a young man, Brougham presented work that Young criticized. Later, Brougham, a Newtonian, attacked Young in a series of nominally anonymous articles. Young wrote and had printed for sale a rebuttal, only one copy of which was sold. These writings are recommended to students of learned, articulate insult.

Another cause of Young's theories being given little consideration at the time was the fact that Newton's stature made disagreement difficult. (Had Newton's infallibility been tarnished by the development of the achromat, which he had considered impossible?)

In addition, Young did not provide an organized theory with mathematical tools while Fresnel did.

Also, while Young was working on his longitudinal wave theory, discoveries were being made in polarization that required transverse waves.

Finally, Young was involved in many activities besides optics.

One view of Young's contribution is as follows: "Dr. Young's Optical Theory for a long time made few proselytes; and several years afterwards, August Fresnel, an eminent French mathematician [actually trained as a civil engineer] took up similar views, proved their truth, and traced their consequences, by a series of labors almost independent of those of Dr. Young. It was not till the theory was thus re-echoed from another land, that it was able to take any strong hold on the attention of the countrymen of its earlier promulgator."

Of himself, Young wrote in "On the History of Optics," Lecture 40 in the Royal Institution series: "... I have discovered a general law of the mutual action of two portions of light interfering with each other, to which no exception has yet been shown."

**Author's confession**

I noticed this 200th anniversary several months ago and suggested that OOP publish an article on the topic. The managing editor proposed that I write one, and I agreed—out of curiosity and with no definite plan—rather than from any sense of expertise. I soon recognized that such work should be left to real historians of science, whose forgiveness I ask for what I have done.

**Further reading**

(Note that some publications have both a reading date and a publication date. The first five references below and much other optics material are found in Miscellaneous Works of the late Thomas Young, M.D., F.R.S., &c., G. Peacock, ed., John Murray, London, 1855, Johnson Reprints, 1972.)

2. "A Letter to Mr. Nicholson, Professor of Natural Philosophy in the Royal Institution, Respecting Sound and Light and in Reply to Some Observations of Professor Robison," Nicholson's Journal, August (1801); Works, 131-9.


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