Thomas Young: physicist, physician and polymath

Phenomenal mind Thomas Young in a 1820s portrait by Sir Thomas Lawrence.

A brilliant and visionary thinker, Thomas Young's mastery stretched from physics and physiology to Egyptian hieroglyphs. But as **Andrew Robinson** explains, Young's ideas were so far ahead of his time that many lay forgotten for decades

Most scientists know of Einstein's reverence for Newton, but few are aware of his admiration for Thomas Young. Yet in his 1931 foreword to the fourth edition of Newton's deeply influential treatise *Opticks*, which had originally been published in 1704, Einstein made the following remark, "Newton's observations of the colours of thin films [were] the origin of the next great theoretical advance, which had to await, over a hundred years, the coming of Thomas Young."

Anyone who has studied physics will know what Young discovered, even if he is much less revered than Newton. In about 1804, Young was the first to demonstrate the phenomenon of interference when he shone the light from a candle through two narrow slits and observed the outcome on a screen. Rather than seeing two bright regions corresponding to the split beam, Young observed a series of bright fringes separated by regions of total darkness.

The only way to explain this result was to suppose that light was a wave and not a stream of particles, or corpuscles, as Newton had firmly maintained. Despite much opposition from the "corpuscularists" over the next few decades, Young's "undulatory" theory of light eventually supplanted Newton's theory by the end of the 19th century. Indeed, Maxwell and others reconceived light purely as an electromagnetic wave.

Then, in 1905, Einstein brought the theory of light full circle. In seeking to explain the photoelectric effect, whereby only light above a certain frequency can eject electrons from a metal, Einstein showed that light must be a stream of particles after all. Shortly afterwards, physicists were led to the revolutionary conclusion that both views were correct: light can indeed behave as a particle *and* a wave. However puzzling, this wave–particle duality is now scientific orthodoxy.

Young's double-slit experiment has therefore become much more than a historically important event, since it can be used to demonstrate both wave and particle behaviour. Repeated time and again with apparatus that is unimaginably more sophisticated and sensitive than Young's candle, slits and screen, the double-slit experiment encapsulates, as Richard Feynman said in his celebrated *Lectures on Physics*, the "heart of quantum mechanics" and its "only mystery".

Indeed, when *Physics World* readers were asked in 2002 to name their most beautiful experiments in physics, Young's experiment ranked at number five (*Physics World* September 2002pp19–20). Moreover, the poll was topped by a 20th-century version of the double-slit experiment, in which individual electrons, rather than a continuous beam of light, are made to interfere.

Although Young's work on the interference of light was his most important achievement, he also made key discoveries in engineering, physiology and philology. He is, for example, well known to both engineers and physicists for "Young's modulus", a fundamental measure of elasticity defined as the ratio of the stress acting on a body to the strain produced. Open any book on the science of vision, and Young will be mentioned as the physiologist who first explained how the eye can

Andrew Robinson is literary editor of *The Times Higher Education Supplement* and author of a new biography of Thomas Young entitled *The Last Man Who Knew Everything* (2006 Pi Press), e-mail andrew.robinson@thes.co.uk. He also wrote *Einstein: A Hundred Years of Relativity* (2005 Palazzo)

focus on objects at varying distances; who discovered the phenomenon of astigmatism; and who first proposed (in 1801) the three-colour theory of how the retina responds to light, which had to wait over 150 years before being confirmed experimentally. Lastly, if you visit the British Museum or read any book on the languages and scripts of ancient Egypt, you will find Young credited for some seminal detective work in deciphering the Rosetta stone and the hieroglyphic script. This led to Jean-François Champollion's breakthrough in understanding how to read the hieroglyphs in 1822. Young's Egyptian research was greatly assisted by his scholarship in ancient Greek and his phenomenal powers as a linguist. This enabled him to compare the vocabulary and grammar of some 400 languages and thus to introduce the term "Indo-European" in 1813 to describe the family of languages that includes Greek, Latin and Sanskrit.

His achievements were aptly summarized by the Nobel laureate Philip Anderson last year, who wrote that "Thomas Young elucidated the optics of the eye, the wave theory of light, the laws of elasticity, the nature of the Egyptian hieroglyphic writing, and Lord knows how many other subjects".

Young the visionary

Born in Somerset in the west of England on 13 June 1773, Young was a child prodigy, notably in languages. However, he was not wealthy and needed a profession. He eventually chose medicine and in 1792 moved to London to begin his medical training with the help of an uncle who was a successful physician. After further spells at Edinburgh and Göttingen universities and at Emmanuel College, Cambridge, he returned to London to begin medical practice in 1800.

Such were his talents that his fellow students at Cambridge dubbed him "Phenomenon Young" with a mixture of respect and derision. "Physicist, physician and Egyptologist" is how encyclopedias struggle to summarize this unique polymath. But his expertise extended well beyond these vast fields of knowledge. In 1802–03, while not yet 30, Young gave a course of lectures covering virtually all of known science in his role as professor of natural philosophy at the newly founded Royal Institution in London. It is doubtful whether these lectures have ever been surpassed in their scope and in their boldness of insight, even by Michael Faraday, the brightest luminary of the Royal Institution. As a result, Young's lectures were reprinted as recently as 2002.

No wonder, then, that Young was elected a fellow of the Royal Society when he was barely 21 and became its foreign secretary at 30. (Had he wished it, he could most probably have been elected the society's president in 1827 when Sir Humphry Davy had to retire.) If Nobel prizes had existed in the 19th century, Young would undoubtedly have received one, possibly two – in physics for his work on the wave theory of light, and in physiology for his studies of the human eye and vision.

The physicist and physiologist Hermann von Helmholtz was in no doubt of Young's greatness. In the 1850s he stumbled across Young's forgotten three-colour theory of vision and developed it into what is today known as the Young–Helmholtz theory. "He was one of the most acute men who ever lived," Helmholtz famously wrote, "but had the misfortune to be too far in advance of his contemporaries. They looked on him with astonishment, but could not follow his bold speculations, and thus a mass of his important thoughts remained buried and forgotten in the *Philosophical Transactions of the Royal Society* until a later generation by slow degrees arrived at the rediscovery of his discoveries, and came to appreciate the force of his arguments and the accuracy of his conclusions."

Young's massive Royal Institution lectures, published in 1807 as *A Course of Lectures on Natural Philosophy and the Mechanical Arts*, are unquestionably his greatest work. The book contains a catalogue of about 20 000 articles in many different languages, some dating back to those written by ancient Greek scholars, along with detailed comments and annotations by Young. Lord Rayleigh, the first British physicist to receive a Nobel prize, often referred to Young's lectures in his own research. Speaking at the Royal Institution in 1899 on the centenary of its founding, Rayleigh did Young the signal honour of expounding some lesser-known aspects of the lectures.

According to the official record, Rayleigh announced that "Young occupied a very high place in the estimation of men of science – higher, indeed, now than at the time when he did his work. His *Lectures on Natural Philosophy*…was a very remarkable book, which was not known as widely as it ought to be. Its expositions in some branches were unexcelled even now, and it contained several things which, so far as he knew, were not to be found elsewhere".

Rayleigh concluded his lecture by noting that he had possibly left the impression that Young knew everything. But just to show that Young "was after all human", Rayleigh mentioned a passage from Young's lectures in which he stated that there was no immediate connection between magnetism and electricity.

A mastery of mechanics

Despite such rare lapses, the mathematician Sir Joseph Larmor wrote in 1934 that the *Lectures on Natural Philosophy* were "the greatest and most original of all general lecture courses". Today's physicists are likely to be astonished, and sometimes disturbed, by Young's far-sightedness and range of interests, which went far beyond his double-slit experiments.

While at Cambridge, his fellow students dubbed him "Phenomenon Young" with a mixture of respect and derision

At a Glance: Thomas Young

- Thomas Young is best known for demonstrating the phenomenon of interference, which led him to promote the wave theory of light in opposition to Newton's then-dominant idea that light was composed of particles
- A polymathic mind, Young gave a brilliant series of lectures to the Royal Institution in 1802–03 containing insights into mechanics and heat that were only fully appreciated years later
- He was the first person to use the term "energy" in its modern scientific sense as a measure of a system's ability to do work
- Young was also the first physicist to estimate the diameter of a molecule
- He even linked heat and light as one phenomenon, and proposed the modern concept of a continuous spectrum of radiation, in which wavelength rises as frequency falls
- In addition to his work in physics, Young was a celebrated physiologist, physician and linguist, who inaugurated the decipherment of Egyptian hieroglyphs

High society This hand-coloured etching by James Gillray, dated 1802, satirizes a discourse at the Royal Institution (RI) in London. It depicts Young – professor of natural philosophy at the RI – experimenting on one of its managers, probably with nitrous oxide, while being watched by his fellow lecturer the chemist Humphry Davy, who holds a pair of bellows. The man standing far right with the bulbous nose is Count Rumford, the physicist who founded the RI in 1799. The audience response varies from solemnity to hilarity.

For example, in the section of the *Lectures* on mechanics, Young used the term "energy" for the first time in its modern scientific sense – i.e. as a measure of a system's ability to do work. In the lecture "On confined motion", Young wrote, "[S]ince the height, to which a body will rise perpendicularly, is as the square of its velocity, it will preserve a tendency to rise to a height which is as the square of its velocity, whatever may be the path into which it is directed, provided that it meets with no abrupt angle…The same idea is somewhat more concisely expressed by the term energy, which indicates the tendency of a body to ascend or to penetrate to a certain distance, in opposition to a retarding force."

Elsewhere in the *Lectures*, in a chapter entitled "On collision", Young went further and defined this energy as the mass of a body multiplied by the square of its velocity. "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," he wrote. "Thus, if a weight of one ounce moves with a velocity of a foot in a second, we may call its energy 1, if a second body of two ounces [has] a velocity of three feet in a second, its energy will be twice the square of three, or 18." It is amazing to think that we now define kinetic energy in classical physics in exactly the same way, apart from one comparatively trivial refinement, as $E = {}^1\!/_2 mv^2$.

Young sought to unify as many physical phenomena as possible within a single theoretical structure

Another section of the book deals with elasticity, or what Young called "passive strength". In his preface, he wrote, "The passive strength of materials of all kinds has been very fully investigated, and many new conclusions have been formed respecting it, which are of immediate importance to the architect and to the engineer." Later in life, Young applied this thinking to practical problems such as the building of ships and bridges.

It is here that Young defined his modulus of elasticity: "[W]e may express the elasticity of any substance by the weight of a certain column of the same substance, which may be denominated the modulus of its elasticity, and of which the weight is such, that any addition to it would increase it in the same proportion, as the weight added would shorten, by its pressure, a portion of the substance of equal diameter."

Although this particular definition was cumbersome and obscure – indeed, Young was much criticized for his sometimes opaque writing – his concept was correct. Today, Young's modulus is defined as stress divided by strain. He also studied how materials bend and shear, introduced shear as a form of elastic strain, and observed that the resistance of a body to shear is different from its resistance to extension and compression. However, he did not introduce a separate shear modulus; Young's modulus applies only to longitudinal stress and strain.

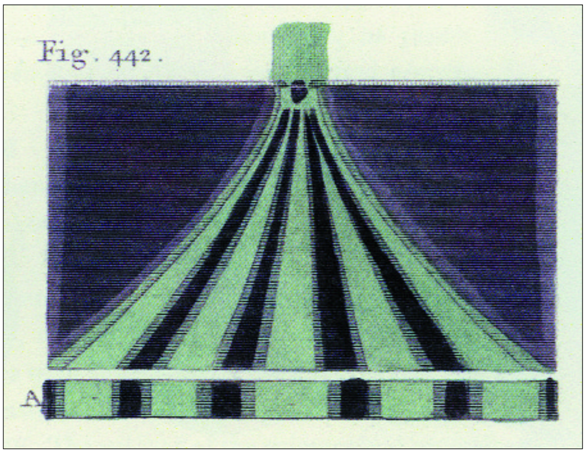
Stress, strain and shear naturally led Young to think about the microscopic origin of the forces that hold materials together as manifested in their tensile strength, which is their resistance to breaking under tension. Although most physicists did not totally accept the idea of atoms and molecules as real entities until the early 20th century, Young was, as usual, ahead of the pack. In fact, he was the first physicist to make an experimental estimate of the diameter of a molecule, based on his study of capillary action and surface tension in liquids. This was more than 50 years before the similar estimates of Lord Kelvin.

It was Rayleigh who first pointed out Young's achievement from his study of the latter's lectures in about 1890. As Rayleigh's son, the physicist Robert John Strutt, explains in a biography of his father, "Tearing a liquid column in half…creates two surfaces. These surfaces have a tension, and Young showed that the range of molecular forces could be found by comparing the surface tension with the tensile strength."

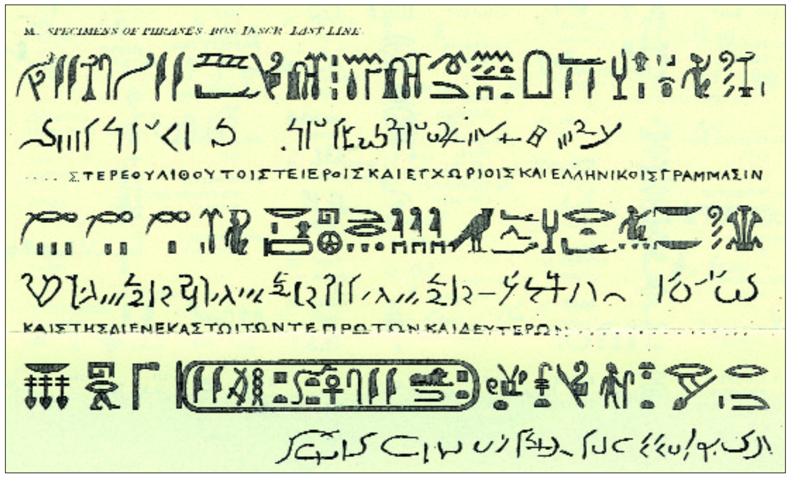
Young estimated that the cohesive molecular forces in pure water vapour extended to no more than about 250 millionths of an inch (about 60 nm). From this, he estimated the diameter of liquid water molecules to be "between the two thousandth and the ten thousandth millionth of an inch" (about 0.05–0.25 nm). Young later wrote of the "ultimate atoms of bodies, of water, for instance, about a million of which would occupy a length equal to the diameter of one of the red particles of blood". We now know, of course, that a water molecule is about 0.2–0.3 nm in size.

Rejecting caloric

When Young turned his attention to heat, he wholeheartedly embraced the avant-garde idea that it was caused by the motion of atoms. In doing so, he rejected the dominant idea of the day that heat was a substance



Beyond the fringes In 1807 Young published a seminal book entitled *A Course of Lectures on Natural Philosophy and the Mechanical Arts*. Based on lectures he gave at the Royal Institution, the book was an inspiration for many later physicists, including Helmholtz, Rayleigh and Larmor. This image of the double-slit experiment shows how "two portions of coloured light, admitted through two small apertures, produce light and dark stripes or fringes by their interference".



Polymath Young was not just a scientist, but also a talented linguist who carried out vital detective work in deciphering the Rosetta stone and Egyptian hieroglyphic script. Taken from Young's article on Egypt in the 1819 supplement to the *Encyclopaedia Britannica*, this image shows phrases from the last line of the Rosetta stone in hieroglyphic (monumental) script, demotic (cursive) script and the Greek alphabet. Young's research led to Jean-François Champollion's breakthrough in 1822 in understanding how to read hieroglyphs.

– an imponderable fluid then called caloric – that was said to increase within a body as it got hotter. Although Young was aware of Count Rumford's experiments on heat in the late 1790s, which had already begun to undermine the caloric theory, again Young was well ahead of his time.

However, he went further, linking heat and light as one phenomenon in a passage of *Lectures on Natural Philosophy* that is so clear-sighted to be worth quoting in full. In it he proposed the modern concept of a continuous spectrum of radiation, passing from invisible ultraviolet through visible light to invisible infrared, with the wavelength increasing and the frequency decreasing.

"If heat is not a substance," he wrote, "it must be a quality; and this quality can only be motion. It was Newton's opinion that heat consists in a minute vibratory motion of the particles of bodies, and that this motion is communicated through an apparent vacuum, by the undulations of an elastic medium, which is also concerned in the phenomena of light."

Young then introduced his controversial undulatory theory: "If the arguments which have lately been advanced, in favour of the undulatory nature of light, be deemed valid, there will be still stronger reasons for admitting this doctrine respecting heat, and it will only be necessary to suppose the vibrations and undulations, principally constituting it, to be larger and stronger than those of light, while at the same time the smaller vibrations of light, and even the blackening rays [ultraviolet light], derived from still more minute vibrations, may, perhaps, when sufficiently condensed, concur in producing the effects of heat."

He concludes this passage by saying that "these effects, beginning from the blackening rays, which are invisible, are a little more perceptible in the violet, which still possess but a faint power of illumination; the yellow green afford the most light; the red give less light, but much more heat, while the still larger and less frequent vibrations [infrared light], which have no effect on the sense of sight, may be supposed to give rise to the least refrangible rays, and to constitute invisible heat."

A unifying mind

In the *Lectures*, we see Young doing what today's physicists also try to do: unify as many physical phenomena as possible within a single theoretical structure. Of course, he failed in many respects, especially with electricity and magnetism. But it is astonishing that Young achieved as much as he did, guided as he was by his deeply informed historical and contemporary understanding of other scientists' work, by his own experiments and, most importantly, by his formidable intuition.

In 1855 Young's first biographer, the Cambridge mathematician and astronomer George Peacock, remarked on Young's ability with an air of slight exasperation. "Important and difficult steps", he wrote, "are passed over as manifest, terms are neglected as insignificant, analogies take the place of proofs, and we are surprised to find ourselves at the end of an investigation, even within the limits of space which would commonly be deemed hardly sufficient to master the difficulties which meet us at the beginning. But his rare sagacity hardly ever deserts him."

For those of us lesser mortals who feel instinctively drawn to geniuses who are versatile, Thomas Young is guaranteed to be an inspiration; while others whose taste is for genius with a narrow focus are bound to regard Young with scepticism. What is undeniable, though, is that he really did approximate to "the last man who knew everything" – however much Young himself would have denied this. We can safely say, with the endless expansion and bifurcation of knowledge, that noone will be able to stake this awesome claim ever again.

More about: Thomas Young

G Peacock 1855 *Life of Thomas Young, M.D., F.R.S.* (London, John Murray); republished 2003 (Bristol, Thoemmes Press)
T Young 1807 *A Course of Lectures on Natural Philosophy and the Mechanical Arts* two volumes (London, Joseph Johnson); republished in four volumes 2002 (Bristol, Thoemmes Press)
T Young 1855 *Miscellaneous Works of the Late Thomas Young, M.D., F.R.S.* three volumes (London, John Murray); republished 2003 (Bristol, Thoemmes Press)