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Science, Literature, and Human Thought

As I have mentioned elsewhere,[1] that morning star of modern chemistry, Joseph Black, in the words of Lord Brougham, "liked to dwell on the manner in which discoveries are made, and the practical effect resulting from them in changing the condition of men and things." That task of illumination has often been accomplished in greater or less detail by historians of science and by economists. Equally important, however, is the task, somewhat neglected, of tracing the influence of scientific discoveries and the development of scientific theories upon human thought. That formidable task may perhaps be attempted for the present purpose in bare outline by undertaking a brief survey of the reflections of science in literature through the ages.

Man's Earliest Literature

The association between literature and science may be traced back to remote times when each of these two great fields of human thought and endeavour existed only in a rudimentary form. Even the Ebers Papyrus, the so-called "oldest book in the world," written some thirty-five centuries ago in a cursive form of the chiseled hieroglyphs of ancient Egypt, has a strong scientific interest. Through the earlier labors on the Rosetta Stone of the eminent physicist, Thomas Young, conjoined with those of Champollion, it became possible to identify the Ebers Papyrus as a primitive pharmacopoeia, and to reveal its strange collection of more than eight hundred prescriptions and remedies.

Dating from much later, about the seventh century B.C., and still extant, are numerous Babylonian tablets from the royal library of the Assyrian king, Assurbanipal; these are inscribed with practical information concerning what would now be called the technology of metals, glass, and other materials. Other tablets of this kind date from a much earlier period. Noyes, in his poem, "The Torch-Bearers," refers to records of these ancient days when he writes:

> The eclipses timed in Babylon help us now
> To clock that gradual quickening of the moon,
> Ten seconds in a century. Who that wrote
> On those clay tablets could foresee his gift
> To future ages?

Aristotle, in the fourth century B.C., held that matter was continuous and capable of infinite subdivision. Epicurus, somewhat later, revived the atomistic speculation of earlier Greek philosophers, according to which matter is discontinuous or grained. This Epicurean philosophy was expounded in the first century B.C. with passionate eloquence and power by the Roman poet Lucretius. His didactic poem *De Rerum Natura* ("Concerning the Nature of Things") expounds the thesis that the gods, like men, are mortal, and that the atom alone throughout the universe is eternal and incorruptible. This jewel of Latin literature is the earliest literary work of the first rank which deals with science.

Of Tyrian purple, the imperial colour, the most precious dye of the ancient world, Lucretius wrote:

> The purple dye of the shellfish so unites with the body of wool alone, that it cannot in any way be severed, not were you to take pains to undo what is done with Neptune's wave, not if the whole sea were willed to wash it out with all its waters.

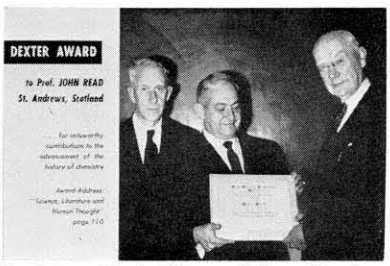
Returning to this theme two thousand years later, Robert Browning exclaimed:

> Who has not heard how Tyrian shells
> Enclosed the blue, that dye of dyes,
> Whereof one drop worked miracles,
> And coloured like Astarte's eyes,
> Raw silk the merchant sells?

There was much intermingling of the mathematical and scientific knowledge and ideas of ancient Greece with those of Persia and Syria, a fuller co-ordination of which took place in Hellenistic Egypt. From about the seventh century A.D. this corpus of knowledge and ideas passed to Islam; and eventually the accumulated knowledge of the Muslim mathematicians, astronomers, medical men, alchemists, and other protagonists of early science, drawn from various sources and augmented during its passage through Islam, percolated into Western Europe.

This passage westward occurred chiefly through Spain, and in the form of Latin translations of Arabic texts. Among the translators were the Englishmen, Robert of Chester and Adelard of Bath, and the Scotsman, Michael Scot. These were pioneers in introducing science into Britain in a literary form, albeit in Latin.

The cover



Dr. Sidney M. Edelstein, secretary of the ACS Division of History of Chemistry, presents the Dexter Award to Prof. John Read at a meeting of the British Chemical Society. Prof. Harry Julius Emeleus (left), president of the Chemical Society (London) also participated in the ceremony.

Prof. Read, whose research interests have been in the field of stereo chemistry, is widely known as a teacher, historian, and author. His pen has contributed notably to illuminating the humanistic values of science.

[1] READ, JOHN, "Humour and Humanism in Chemistry," G. Bell & Sons, London, **1947**, p. 161; "Humor y Humanismo en la Quimica," Aguilar, Madrid, **1953**, p. 164.

Dominating Position of Alchemy

The translators of the twelfth century were succeeded by the encyclopaedists of the thirteenth, whose role was to collect and edit, in manuscript form, the knowledge that had come through to them from ancient Greece and other eastern sources. One of the greatest of these scholastic philosophers, as his name indicates, was Albertus Magnus (1193–1282), also known as *Doctor Universalis*. Some of the Latin scripts were translated into English. There is, for example, in the British Museum, an English manuscript version written in the fifteenth century, of the *Semita Recta* ("Straight Path") an alchemical tract attributed to Albertus. This states that

> "alle metaills been ingendard in therthe of sulphur and mercury . . .Whene reede sulphur and pure and not brennyng renneth in therthe with mercury thereof is ingendrid gold. . .but whene white sulphur renneth to mercury in cleene erthe thereof is ingendrid silvre and hit hath noo difference fro gold but that sulphur in gold is not corrupte but in silvre hit is corrupte."

This manuscript offers an indication of the dominating position of alchemy in the literature of early science. Enduring for more than a thousand years, from the early Christian era until late in the seventeenth century, alchemy was not merely the forerunner of chemistry, animated by visions of the Philosopher's Stone and the *Elixir Vitae*, with their concomitants of wealth and long life. This exoteric alchemy, indeed, was no more than the materialistic phase of a great philosophical system, based upon an esoteric, or spiritual, alchemy. As an integral part of this large system, exoteric, or practical, alchemy took its place beside philosophy, religion, mysticism, astrology, theosophy, and many other elements. In the Middle Ages and later the conceptions and imagery of this larger alchemy found in contemporary literature and art a wide expression of which there is little realization at present. Moreover, the great ocean of alchemical literature, written and printed in many languages, remains a closed book, a book both closed and hermetically sealed, to the literary specialists of our own day.

Much of this literature, in particular of the esoteric kind, is very difficult to interpret. It may be said, however, that according to the fundamental tenets of alchemy, matter possesses an essential unity; the common soul of matter alone is permanent, the body, or outward form, being transitory and transmutable. The sulphur-mercury theory of the constitution of metals, already adumbrated, regards the properties of matter as separate from matter itself. "Sulphur" is merely a name for the property, or principle, of combustibility; "mercury" is the property, or principle, of metallicity and fusibility. The incorporation with matter of these principles in an impure state leads to base metals; in purer states to the noble metals, silver and gold; and in superfine states to the Philosopher's Stone. Sometimes in the Great Work of preparing this potent transmuting agent a third principle, known by such names as "salt" and "magnesia," was considered necessary.

An interesting impression of some of the contributions in English to alchemical literature may be gained from Elias Ashmole's collection of twenty-nine English alchemical writings in verse, which he published in 1652 under the title "Theatrum Chemicum Britannicum." Chief among them are Norton's "Ordinall of Alchimy," Ripley's "Compound of Alchymie," and " 'The Tale of the Chanons Yeoman,' written by our Ancient and famous English Poet Geoffry Chaucer."

The esoteric alchemists were usually deeply imbued with religion, so that their writings abound in references to religious beliefs and doctrines, including, for example, repeated associations of the Christian mystery of the Trinity with the alchemical mystery of the triune Stone. In one of Ashmole's poems, rescued, as he says, "from that Universall Deluge, which (at the Dissolution of Abbies) overflowed our greatest Libraries," the constituents of the Stone are likened to the gold, frankincense, and myrrh of the three Magi:

> Aurum betokeneth heer, owre Bodi than,
> The wych was brought to God and Man,
> And Tus alleso owre Soul of lyfe,
> With Myrham owre Mercurye that ys hys Wife.
> Here be the thre namys fayre and good
> And alle thaye ben but one in mode.
> Lyke as the Trinite ys but on,
> Ryght so conclude the *Phylosofeers Stone.*

Among the minor pieces of Ashmole's collection is a charming little poetical tribute to the magical herb called Lunary, or Moonwort, endowed by alchemists with particular virtues because of the likeness to the crescent moon which they perceived in the shape of its leaves:

> Her ys an Erbe men calls *Lunayrie*
> I-blesset mowte hys maker bee. .
> The Levvis ben rownd, as a Nowbel son,
> And wexsyth and wanyth as the Mon:
> In the meddis a marke the brede of a peni,
> Lo thys is lyke to owre sweght Lunayre.

Chaucer and Norton

Of the major items, those of Chaucer and Norton call for particular notice. Although these two literary presentments of alchemy are separated in time by about a century, they depict in a sense two contemporary aspects of an essentially static subject.

It is fortunate for all who value the literary and humanistic associations of science that Geoffrey Chaucer, "the father of English poetry," devoted one of his "Canterbury Tales" to a delineation of the alchemy of his day; for in the "Canon's Yeoman's Tale" the Canon is an alchemist and the Yeoman is his assistant "labourer in the fire." In this narrative, alive with humanity and illumined with literary charm, Chaucer gives a genre picture of an alchemical laboratory, its denizens, and its goings-on, as vivid and faithful as the later representations, in another medium, of that artist of alchemy *par excellence*, David Teniers the Younger. This "Tale," indeed, is the finest and best known literary work dealing in any language with medieval alchemy.

Chaucer's treatment shows the master-hand of an imaginative poet of the first rank who possessed also an intimate knowledge of the science of his day; indeed, his unfinished "Treatise on the Astrolabe" (1391) was probably contemporaneous with the "Canon's Yeoman's Tale." Of the two Canons under whom the Yeoman served, the first was an uninformed alchemist

of the lowest exoteric type and the second was a pure charlatan and impostor. There is much in this "Tale" showing that the subjective human aspect of the laboratory has changed little in the last six hundred years. Let us "listen in" to one of the many laments of the sorely-tried Yeoman:

> Whan we be ther where we shul exercise
> Oure elvish craft, we seme wondrous wyse,
> Oure termes be so lerned and so queynte.
> I blow the fyr til that myn herte feynte.
> And wit ye how? Ful ofte it happeth so,
> The pot to-breketh, and farwel, al is go. . .
> There never was suche wo or anger or ire
> As when our pot is broke, as I have sayd,
> Every man chideth, and thinketh him ill paid.
> Some sayd it was too long on the fyr-making;
> Some sayde nay, it was on the blowing;
> (Than was I feared, for that was myn office).

Thomas Norton of Bristol was an alchemical adept, endowed alike with a full esoteric knowledge and practical experience of alchemy; according to tradition he was a pupil of the celebrated George Ripley, Canon of Bridlington. Norton was an early member of a long sequence of scientists with poetic tendencies. His "Ordinall of Alchimy," begun in 1477, a long poem consisting of seven chapters following a Probeme, bas perhaps no great literary merit, although Norton is "usually able to scramble home with a rhyme at the end of his line." The archaic language of the poem is attractive, and its account of the beliefs and practices of fifteenth-century alchemy is of great historical value. Norton stresses the esoteric nature of "holi Alchimy," the secrets of which are imparted only under the seal of a "most sacred dreadful Oath:"

> Almighty God
> From great Doctours hath this *Science* forbod.
> And graunted it to a few Men of his mercy,
> Such as be faithful trew and lowly.

The poem shows Norton as a capable laborant and director of practical operations. Like all alchemists he had his trials, and he suffered from the incompetence, "deceipt," and dishonesty of those around him. At one point he was deprived of the result of much labour,

> For when I had my warke well wrought
> Such stale it away and left me nought.

An even greater misfortune befell him when a fair deceiver, the wife of a Bristol merchant, purloined his Elixir of Life, as he says,

> To my greate paine and much more woe:
> Soe in this worke there is no more to saine,
> But that every *Joy* is medled with his paine.

Ben Jonson and Shakespeare

In alchemy, time stood at gaze. Although Ben Jonson's famous play, "The Alchemist," was written more than two hundred years after Chaucer's masterpiece, the central figure, Subtle, like Chaucer's second Canon, is a "cheater" and "coz'ner at large," and an alchemist only by courtesy. Naturally, also, that *ignis fatuus* of alchemy, the Philosopher's Stone, lies again at the heart of the scene. "This day I am to perfect for him," says Subtle of Sir Epicure Mammon,

> The magisterium, our great work, the stone:
> And yield it, made, into his hands; of which
> He has, this month, talked as if he were possessed.

Jonson's play pilloried the familiar chicaneries, frauds, credulities, and superstitions of Jacobean London. Laden with telling wit and biting satire, it made a lasting appeal to the audiences of that age. Much later, in 1661, after the Restoration, Pepys lauded it in his diary as "a most incomparable play." In still later ages, although its alchemical ideas, imagery, and vocabulary had become largely obsolete, Coleridge described its plot as one of the three most perfect ever planned; and Swinburne ranked it as unique and among "the greatest of comic triumphs ever accomplished." As I have written elsewhere,[2] Jonson's "lavish transmutation of alchemical imagery and expressions in this great work of English literature envelops the play in a poetic web of great beauty; at the same time, his command of these alchemical technicalities is so consummate that 'The Alchemist' is one of the best and most accurate repositories of the ideas and vocabulary of seventeenth-century alchemy."

This later period of alchemy was marked by many extravagances, among them the quaint conception that the whole corpus of classical mythology had been designed expressly to record in a concealed and allegorical form the secret doctrines of the so-called "sons of Hermes," or alchemical adepts.[3] Jonson makes great and eloquent play with such classical allusions, in describing what he calls "the manner of our work:"

> The bulls, our furnace,
> Still breathing fire: our argent-vive, the dragon:
> The dragon's teeth, mercury sublimate,
> That keeps the whiteness, hardness and the biting;
> And they are gathered into Jason's helm,
> (The alembic), and then sowed in Mars his field,
> And thence sublimed so often, till they're fixed
> Both this, th' Hesperian garden, Cadmus' story,
> Jove's shower, the boon of Midas, Argus' eyes,
> Boccace his Demogorgon, thousands more,
> All abstract riddles of our stone.

Although Shakespeare evinced no outstanding interest in the science of his day, he wrote of the dawning sun "gilding pale streams with heavenly alchemy." Also, he alluded repeatedly to "the tinct and multiplying medicine," the "medicine potable," "that great medicine," which in the words of Cleopatra to Alexas, "hath with his tinct gilded thee." He deplored the application in warfare of that "villainous saltpetre . . . which many a good tall fellow had destroyed so cowardly"; and in the field of celestial mechanics he based some of his most eloquent poetic imagery upon the ancient Pythagorean conception of the music of the spheres.

Nevertheless, there is no doubt that Shakespeare, no less than Ben Jonson and other contemporary writers, was acquainted with Thomas Digges' "Perfect Description of the Celestial Orbs," a Copernican treatise first printed in 1576 and reissued five times within the next twenty years. But Shakespeare, like others, found little difficulty in accommodating old beliefs of the Ptolemaic or geocentric system in a new framework of the Copernican or heliocentric system of which Digges

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[2] READ, JOHN, "The Alchemist in Life, Literature and Art," Thos. Nelson & Sons, London and Edinburgh, **1947**, p. 40.

[3] READ, JOHN, "Prelude to Chemistry," G. Bell & Sons, London, **1936**, p. 234; The Macmillan Co., New York, **1937**, p. 234.

himself proclaimed, "we may behold such a wonderful symmetry of motions and situations as in no other can be proponed."

Thus, in "A Midsummer-Night's Dream" Shakespeare alludes to "certain stars" that "shot madly from their spheres, to hear the sea-maid's music"; and a beautiful passage in "The Merchant of Venice" runs in this wise:

> Look how the floor of heaven
> Is thick inlaid with patines of bright gold:
> There's not the smallest orb which thou behold'st
> But in his motion like an angel sings,
> Still quiring to the young-eyed cherubins;
> Such harmony is in immortal souls;
> But whilst this muddy vesture of decay
> Doth grossly close it in, we cannot hear it.

As a footnote to these astronomical allusions it may be said that there is evidence that Shakespeare probably saw in the house of the aforementioned Thomas Digges, who was a friend of Tycho Brahé, an engraved portrait of this celebrated Danish astronomer containing certain ancestral names, of which two appear in "Hamlet" as the courtiers Rosencrantz and Guildenstern.

Shakespeare and Ben Jonson were born in the latter half of a century which had already seen great changes in science. At the time of the writing of "The Alchemist," alchemy had passed its zenith and had entered upon a period of decay. Almost a century earlier, Paracelsus had endeavoured to give a new direction to alchemy by allying it with medicine, and in Ben Jonson's day the old alchemy was pursuing a downward course while its new orientation gathered force. The seventeenth century thus witnessed the rise and development of a species of medico-chemistry, known also as iatrochemistry, and sometimes as chymistry. This diversion of alchemy was symptomatic of a much wider and deeper movement.

The opening of that momentous sixteenth century of Shakespeare and Jonson, at which time Paracelsus was a youth at Einsiedeln, had been "marked by a great forward surge of the Renissance, that transitional movement in Europe between the medieval and modern order of Western civilization. Many diverse influences were coming at that time into a common focus. Among them, the impact of the wonderful flood of rediscovered classical knowledge was gathering force; the power of the new art of printing was beginning to take effect; and the confines of the known world were rapidly expanding as a consequence of the voyages of Columbus (1492), Vasco da Gama (1497), and Magellan (1521). Fresh horizons of the material and intellectual world were opening with a rapidity hitherto unknown. Doctrines and conceptions that had held fast throughout the rigid period of medievalism now began to be questioned and assailed."[4]

In this new and stimulating atmosphere there arose many pioneers of a fresh order. Early among them came Luther, whose success in the struggle to burst the bonds of religious orthodoxy and tyrannic authority found a dramatic expression in his public burning of the Papal Bull of Condemnation at Wittenberg, in 1520. Seven years later, Paracelsus similarly condemned the orthodox system of medicine by publicly consigning the venerated writings of Galen and Avicenna to the flames in the market-place of Basel. Sixteen years later still, two more significant upheavals in science found expression in two great works printed in 1543. Copernicus' *De Revolutionibus Orbium Coelestium* revolutionized the most ancient of sciences by asserting that the earth was a planet revolving around the sun, instead of being the hub of the universe, as depicted in the hoary Ptolemaic system of the second century A.D.; and Vesalius' *De Fabrica*, the foundation work of anatomy, brought about an advance of equal importance in biology.

Scientific Revolution of the Seventeenth Century

And so the dawn of the seventeenth century, the day of the rich English literature of Shakespeare, Ben Jonson, Burton, Donne, Campion, and many another, brought with it the dawn of the so-called "scientific revolution," and thereby heralded the birth of modern science. The scientific revolution of the seventeenth century hinged upon astronomy, the oldest of the sciences, and found its inspiration in the law of inertia. The ideas of Galileo (1564–1642) concerning mass and inertia formed the foundation of the first law of motion, as enunciated by Newton (1642–1727), who was born in the year of Galileo's death. Nearly a century and a half after Copernicus' *De Revolutionibus Orbium* (1543), Newton was able in his *Principia* (1687) to effect his grand synthesis of the fundamental dynamical and gravitational problems concerned in the motions of the heavenly bodies. This correlation of dynamics and astronomy, of motion on the earth and in the skies, of the falling apple and the falling moon, lies at the very core of the scientific revolution of the seventeenth century.

Newton's theory of gravitation at once superseded the short-lived vortical theory of Descartes (1596–1650), the great philosopher and mathematician whose *Discours de la méthode* (1637) and axioms ("cogito: ergo sum"; "whatever is clearly and distinctly thought must be true") exerted so great an influence upon the thought of his own and a later age.

In another, widely removed, field of science, Vesalius' masterwork of anatomy, *De Fabrica* (1543), was followed in due course by William Harvey's revolutionary work, *De motu cordis* (1628), dealing with his discovery of the circulation of the blood. A new era had opened also in the study of living organisms.

How many students of the arts—indeed, how many students of the sciences—realize that the scientific revolution, this most fundamental of all changes in human thought, was due in the first place to Italy and found a focal point in the University of Padua? This seat of learning, so ancient and so rich in fame, claimed close associations with Copernicus and Galileo, and it had been mightily enriched by the work of Vesalius and of Harvey's own teacher, the great Fabricius.

Now the scientific view of the enormous advances here so hastily sketched represents only one aspect of the scientific revolution. That revolution had a much wider significance. The new conception of a macrocosm subject to dynamical laws and no longer impelled by invisible hands, and the new knowledge of the living microcosm of man, exerted a profound influence upon

[4] READ, JOHN, "Through Alchemy to Chemistry," G. Bell & Sons, London, 1957, p. 95; "De l'Alchimie à la Chimie," Arthème Fayard, Paris, 1959, p. 141.

the society and general mental attitude of the day. Here is an example of the truism, so important and yet so often overlooked, that the history of science does not exist as an immiscible layer floating upon the stream of general history: but that it is an all-pervading and vivifying ingredient of that stream.

Reaching maturity in the early days of this revolution in scientific thought, Francis Bacon (1561–1626), a great literary figure, is best known to the general reader as the author of the classical essays. Among scientists he deserves equal renown as the author of the *Novum Organum Scientiarum* (1620) and founder of the inductive system of philosophy, based upon experiment, observation, and measurement, of which Robert Boyle was one of the first eminent exponents. Of his contemporaries in English literature, few evidenced any inkling of the coming impact of the scientific revolution upon the whole current of human thought. Perhaps it is not too much to claim that only the two greatest poets of that age, Donne and Milton, had a glimpse of the impending change. "The new philosophy calls all in doubt," wrote Donne. As for Milton, although he adopted the ancient Ptolemaic system in his great epic "Paradise Lost," there is no doubt that he was well acquainted with the informed contemporary view; and he had indeed visited the "famous Galileo, grown old."

The Royal Society

It was not until after the upheavals of the Civil War and the unease of the Commonwealth that science and literature were brought into close relationship in England, with the foundation of The Royal Society by King Charles II in 1660. This most famous of all scientific societies, set out with the avowed aim of improving and enlarging "the empire of operative philosophy by the real effects of the experimental." It is significant that among its early members eminent scientists of the calibre of Boyle, Hooke, and Newton mingled with men of letters like Evelyn, Waller, Cowley, Dryden, and Pepys, and that Christopher Wren was one of the early presidents. This intimate association gave impetus to the profound change that was now penetrating through contemporary literature to the general thought of the new epoch, a change that has been described as a shifting of values from the next world to this.

Moreover, this interplay of science and literature infused a new style into literary writings. From the days of Chaucer, the vocabulary of science had infiltrated gradually into the English language, but science was now destined to influence increasingly the method of literary expression. The Royal Society insisted upon "a close natural way of speaking, positive expressions, clear senses, a native easiness, bringing all things as near the mathematical plainness as possible." Contemporary writers caught this fashion to such a degree that Dryden, expressing his independence of outlook in his work "Annus Mirabilis," wrote "My whole discourse is sceptical, according to the way of reasoning initiated in the modern inquisition of the Royal Society."

It would be wrong however to depict writers of that day as subservient to the Royal Society. While learning from the Society they often administered a wholesome corrective to the excesses of its Fellows, some of whom were given to trivialities and extravagances. To be a member of a Society owning the King as patron carried a cachet which attracted many so-called virtuosi, amateurs of science whose uninformed activities and writings tended to bring discredit upon the learned academy to which they belonged. Samuel Butler, the lively-minded author of "Hudibras," wrote a particularly pungent and amusing skit which described a group of these virtuosi gazing through a telescope at a great battle on the moon, in which a monstrous elephant played havoc among the lesser combatants; only to find, after entering their account in the *Transactions*, that the fighting men were flies on the lens, and that the elephant was "a mouse that, by mishap, had caught himself, and them, in the optic trap."

At a later date Swift was equally devastating in his satirical description of Gulliver's encounter at the College of Lagado with learned professors engaged in such pursuits as extracting sunbeams from cucumbers; moreover, he concocted an ingenious analogy between the different grades of poets and the wonders of the microscopic world, which had been first laid bare in Hooke's "Micrographia":

> So Naturalists observe a flea
> Has smaller fleas that on him prey;
> And these have smaller fleas to bite 'em
> And so proceed *ad infinitum*.

At this time, in the early years of the eighteenth century, it became a popular pastime among men of letters to poke fun at scientists and to satirize them and their publications. Swift must have devoted serious study to astronomy, before attributing to the astronomers of Laputa the discovery of two satellites of Mars, an extraordinary speculation which was verified in 1877. Perhaps, however, it was Addison, of all the writers of that period, who had the greatest feeling for science; he and Steele certainly catered in their periodicals to readers having an interest in this fashionable subject, the *dernier cri* of that day.

The general tendency in the literature of this dawn of the "Age of Reason," a tendency induced by the mechanistic view of the universe, was an endeavour to rationalize religious beliefs. Richard Bentley, the great Cambridge scholar and critic, actually applied to Newton in support of Christianity, and derived satisfaction from Newton's reply that

> "the planetary system argues a first cause not blind and fortuitous, but very well skilled in mechanics and geometry."

There was little in Newton's reply, as generally in the writings of that age, to satisfy the longings of a soul in search of God. As Archbishop William Temple wrote some two centuries later:

> "Science aims at explaining the world—that is, making it satisfactory to the mind. . .But the mind is not only logical, but also moral, and will not be content with an account of the world which does not demonstrate its morality."

The new knowledge became so much of a vogue in this era that attempts were made by writers in various countries to bring it before the reading public in simple and understandable terms. First and foremost among them was Fontenelle, nephew of Corneille, and in Voltaire's opinion the most universal genius of his day.

Living to within a month of his century (1657–1757), this remarkable man spanned the passage from the scientific revolution of the seventeenth century to the "Age of Reason" of the eighteenth. His charming book entitled *Entretiens sur la pluralité des mondes* was first published in 1686, and it was translated into English as "Conversations on the Plurality of Worlds." Fontenelle's method of brightening science was to expound it to a lovely countess in a beautiful garden by moonlight. They look at the heavens, and the expositor observes that "Philosophy is now become so mechanical that they will have the World to be in Large what a Watch is in small." The countess replies, "I value it the more since I know that it resembles a Watch, and the more plain and easy the whole order of Nature seems to be, to me it appears the more admirable."

By the side of Fontenelle we may place the Italian, Algarotti, who, in 1732 gave an equally attractive exposition, to a charming Marchesa, of the latest theories of light in his book, *Il Newtonianismo per le Dame.* A typical English work of the same kind appeared later under the title, "The Young Gentleman and Lady's Philosophy, in a continued survey of the Works of Nature and Art; By Way of Dialogue."

Birth of Modern Chemistry

It is a remarkably significant fact, both in historical science and in the development of our modern civilization, that the scientific revolution of the seventeenth century stopped short at chemistry: this because chemistry is based fundamentally upon obscure principles, the elucidation of which came very slowly after prolonged speculation and experiment. As early as 1674, John Mayow, a young Cornishman who practiced medicine at Bath, had carried out some remarkable investigations on the fundamental problems of combustion and respiration; but no appreciable advance upon the work and views of Boyle, Hooke, and Mayow in the later seventeenth century was found possible for another hundred years, owing largely to lack of knowledge of ways of manipulating and characterizing gases, all of which were regarded at that time as ordinary air in different states of purity. Meanwhile chemical thought was dominated by a misleading theory, according to which a burning body emitted an imaginary principle called phlogiston. Suddenly, however, in the second half of the eighteenth century, a great change came over the chemical scene, when the combined researches of Black, Scheele, Priestley, and Cavendish enabled Lavoisier to put forward the modern interpretation of burning, or combustion, as combination with a gaseous component of the atmosphere. This was discovered by Priestley in 1774 and later named oxygen by Lavoisier. With the substitution of the positive oxygen theory for the negative theory of phlogiston, modern chemistry was born. Soon afterward, in 1808, "the abolition of the old ideas and the accumulation of accurate quantitative data led to the formulation by John Dalton of that comprehensive Atomic Theory whose innumerable ramifications form the nervous system of the wonderful body of physical science as we know it today."[5]

From the later decades of the eighteenth century onward applied chemistry also made rapid advances. The development of the heavy-chemical industries set in with improved methods for the large-scale manufacture of sulfuric acid, the discovery of the Leblanc process for making soda, the advent of bleaching powder, and many associated advances in allied industries. In another field of chemistry the introduction of coal gas as an illuminant, in 1792, foreshadowed the birth of organic chemistry and of its great industries based upon coal tar.

The acceleration in the progress of science and its application to industry, synchronizing with the invention of Watt's steam-engine, Cartwright's power-loom, and other mechanical devices led to the so-called industrial revolution in Britain. The growth of factories, the concentration of population in the coal areas, and the decline of agriculture brought about great changes in the social structure of the country. At the same time the further discoveries and ideas of Erasmus Darwin, Davy, and other scientists and thinkers justified Erasmus Darwin's pronouncement that they "enlisted Imagination under the banner of Science."

The Romantic Movement and Science

This world of speculation and revolutionary thought witnessed a literary renaissance known as the Romantic Movement, in which Wordsworth (1770–1850) was the leader and outstanding figure of a school including such famous poets of the time as Keats, Coleridge, and Shelley. The earlier English poets, notably Dryden and Pope, had written in the classical style of Latin poetry; they dealt, often satirically, with society, politics, and moral theories, regarding man's life objectively, and relegating Nature to gardens and artificial pastorals. The new Romantic poetry, heralded by such forerunners as Crabbe, Cowper, and Blake, sought inspiration, both in lyrical and dramatic form, in the common feelings and ideas of ordinary folk, and in Nature. The style was characterized by simple language, with a variety of meters replacing the former heroic couplet.

The Romantic Movement was induced by the mechanistic nature of scientific theory and the growing revolt of the aesthetic sense against the effects of the industrial revolution; it came as a literary reaction against materialism, a reaction sustained also by neo-Platonic ideas, and its participants found refreshment in turning from the ugliness of factory and mine to a contemplation of rustic life and the calm delights of Nature. At the same time it may be held that in Shelley, the poet, as in Newton, the scientist, there was no impassable gulf between science and neo-Platonism.

Wordsworth, perhaps more than any other poet, gave his soul to Nature; and the spirit of the Romantic revival was that of a return to *real* nature, in contrast to Dr. Johnson's *rational* nature of the preceding "Age of Reason." Wordsworth brooded in his poetry over the profound problem of the relation of scientific thought to the spiritual life. He viewed man as a spiritual being in whom poetry and all that it represents should come before science, seeing that true poetry raises thought and feeling into a higher region of imagination which is the home of the spiritual life. How-

[5] READ, JOHN, AND GUNSTONE, FRANK D., "A Text-Book of Organic Chemistry," G. Bell & Sons, London, 1958, p. 26.

ever, Wordsworth, "the poet of Nature and of Man," must not be regarded as opposed to science and scientists; indeed, as he makes clear in "The Prelude," one of his abiding memories of Cambridge was of

> Where the statue stood
> Of Newton, with his prism and silent face,
> The marble index of a mind forever
> Voyaging through strange seas of thought alone.

To Wordsworth, poet and scientist were "twin labourers, and heirs to the same hopes," and he gloried in the achievements of mathematics with "its independent world, created out of pure intelligence." His liberal attitude of mind finds expression in his lines:

> Happy is he who lives to understand
> Not human nature only, but explores
> All natures,—to the end that he may find
> The law that governs each.

The interplay at this time between science and literature was personified in the close friendship existing between Coleridge and Humphry Davy, of whom Coleridge said that "if Davy had not been the first Chemist, he would have been the first Poet of his age." Davy was a friend also of Sir Walter Scott, and Lockhart records an occasion at Abbotsford when "the modesty of their mutual admiration was a memorable spectacle." Upon another occasion, in 1805, Lockhart, in referring to a meeting of Davy and Scott in the Lake District, wrote: "I have heard Mr. Wordsworth say, that it would be difficult to express the feelings with which he, who so often had climbed Helvellyn alone, found himself standing on its summit with two such men as Scott and Davy."

Nineteenth Century: Intellectual Readjustment

Wordsworth died in 1850. Nine years later Charles Darwin published his epoch-making work on the "Origin of Species," of which Huxley said: "It is doubtful whether any other single book, except Newton's *Principia*, has worked so great and so rapid a revolution in science, or made so deep an impression on the general mind." Darwin expounded his evolutionary theory with a literary clarity which also distinguished the writings of T. H. Huxley and other contemporary scientists. These writings shook the foundations of religious belief and brought forth a great literature, for literature must inevitably keep abreast of fundamental advances in scientific thought and of the effects of scientific discovery on social conditions.

There ensued a period of intense intellectual doubt and readjustment. Of the great literary figures of the Darwinian period, some—in particular Carlyle—affected to ignore the birth of a new epoch; others, including Arnold, Clough, and George Eliot, were baffled in trying to reconcile the claims of science and religion in this new chapter in the story of man; Meredith accepted the evolutionary doctrine with a buoyant optimism, but among them all, Tennyson stood out as the great interpreter of the mood of that troubled age.

Tennyson, like his contemporaries, Robert Browning and Matthew Arnold, was deeply interested in science, particularly in astronomy. In his poetical references to the starry heavens he blends lyrical beauty with scientific truth:

> Many a night from yonder ivied casement, ere I went to rest,
> Did I look on great Orion sloping slowly to the West.
> Many a night I saw the Pleiads, rising through the mellow shade,
> Glitter like a swarm of fire-flies tangled in a silver braid.

In some respects Tennyson even anticipated Darwin's statement of evolutionary doctrine; moreover, according to the scientist, Romanes, he recognized the operation of Natural Selection in advance of Darwin. Holding to his beliefs on immortality and Christianity, he realized that science is not immutable and that human knowledge is restricted:

> Our little systems have their day,
> They have their day and cease to be:
> They are but broken lights of thee,
> And thou, O Lord, art more than they.

Until the coming of fuller knowledge, Tennyson foresaw no reconciliation between Faith and Science: each had its own sphere, and meanwhile Faith stood beyond either proof or disproof. As the eminent physicist, Andrade, has expressed it in our own day: "Science has proof but no certainty: religion has certainty but no proof."

In the earlier words of Goethe, the only supreme poet who having a practical acquaintance with science, sought out truth in general:

> "The greatest happiness of the thinking man is to have fathomed those things which are fathomable, and to reserve those which are unfathomable for reverence in quietude."

Tennyson welcomed scientific discovery, and to him evolution implied progress based upon the steadying influence of tradition. As he proclaimed in "Locksley Hall," he

> rather held it better men should perish one by one,
> Than that earth should stand at gaze like Joshua's moon in Ajalon!
> Not in vain the distance beacons. Forward, forward let us range,
> Let the great world spin for ever down the ringing grooves of change.
> Thro' the shadow of the globe we sweep into the younger day:
> Better fifty years of Europe than a cycle of Cathay.

In contrast to the mild optimism of Tennyson and Meredith stand the tragic questionings of Thomas Hardy, with his insistence upon a helpless insignificance of the individual that is only stressed by the evolutionary progress of the type. The chronic melancholy which is taking hold of the civilized races with the decline in the belief of a beneficent Power, as he expresses it in "Tess of the D'Urbervilles," falls into line in his philosophy with that indifferent ruling force of that greatest of all his works, "The Dynasts":

> Like a knitter drowsed,
> Whose fingers play in skilled unmindfulness,
> The Will has woven with an absent heed
> Since life first was, and ever so will weave.

Hardy, taking first rank as novelist, poet, historian, and philosopher, also evinced a lively interest in science. He enjoyed bringing his perceptive mind to bear upon intelligible expositions even of its abstruse branches. "Tell me in simple language what you are doing just now in organic chemistry," he said to me on one of my visits to him at Max Gate, Dorchester, in the 1920's; and he showed a remarkable appreciation of a field of discussion ranging from the nature of right- and left-

handed molecules to asymmetric physiological action and the direction of the spirals of climbing plants. One of his penetrating questions I may record. "Here in Dorset," he said, "the sun passes from east through south to west, and the runner bean climbs in a dextral spiral. Have you noticed whether it takes on a sinistral spiral in Australia, where the sun passes from east through north to west?"

What of the Twentieth Century?

The widespread development of science has become increasingly evident in the literature of the twentieth century, particularly in the writings of men with scientific training. In this field, H. G. Wells, with his blend of scientific and creative instincts, attained a prominent place with his imaginative novels and his studies of contemporary social life and problems. In a different field, Henry Havelock Ellis displayed a literary instinct in his remarkable psychological and sociological works. Psychology is fast attaining the status of a science, and the influence of such psychologists as Freud and Jung upon modern literature and thought is manifest. Typical of later imaginative novels by authors with scientific and technological insight are Nevil Shute's "No Highway" and Nigel Balchin's "Small Back Room." The popularizers of science, also—the modern Fontenelles—have included such scientific specialists as Eddington and Jeans, with their expositions of current views of the universe.

Science has been claimed to foster a curious literary style of the modern epoch, based essentially upon the habit of Lewis Carroll (C. L. Dodgson), the creator of "Alice," in using words, much as in another context he used mathematical symbols. This tendency found a clear expression in Ezra Pound's statement that "poetry is a sort of inspired mathematics, which gives equations, not for abstract figures, triangles, spheres, and the like, but equations for human emotions."

There is naturally a tendency to introduce specialized scientific words into the vocabulary of the poet and imaginative writer; but a contemporary scientist, P. E. Spielmann, in commenting from this point of view upon the writings of James Joyce and Henry Crosby, remarked that "in a poem by the latter all the words are completely new, completely incomprehensible," adding that

> "this separation of a word from any meaning evidently links with the 'abstract-making' mentality of the artist that attaches more importance to the curve than to the body from which it was taken, and also connects with the alchemists who tried to separate the properties of matter from matter itself."

Here we find a scientist concluding that the contemporary arts in general—pictorial art, architecture, music, poetry— have been changed "by the unjustifiable application of scientific theory to the roots of artistic creation . . . with loss of beauty and emotion." On the other side of the tree of scientific knowledge, bearing fruit of such exceeding bitterness, stands the man of letters, Aldous Huxley, offering in his book "Ape and Essence" a merciless satire on both science and human-kind in this "atomic age."

Some time ago I wrote that "the intimate chemical and physical knowledge that man has now acquired of his environment represents the greatest of all his intellectual achievements": pointing out, however, that in order to gather the fruit of this great tree of knowledge he "must learn to master and control himself as he has learned to master and control nature."[6]

There is no natural law preventing him from so doing. When he attains this consummation, for which all must hope and work, man will at last witness the realization of the eloquent prophecy of Isaiah:

> "The wilderness and solitary place shall be glad for them; and the desert shall rejoice and blossom as the rose. . .Then the eyes of the blind shall be opened, and the ears of the deaf shall be unstopped. Then shall the lame man leap as an hart and the tongue of the dumb sing, for in the wilderness shall waters break out, and streams in the desert. . .They shall obtain joy and gladness, and sorrow and sighing shall flee away."

[6] NEWMAN, JAMES R. (ed.), "What is Science?" Simon & Schuster, New York, 1955, p. 194.