Text of the 2004 Essex Hall Lecture by David Williams

Lessons from Joseph Priestley

1. Introduction

At home, I have on the wall an engraving by C Turner ARA, published in 1836, of a painting by a late Enlightenment artist — Henry Fuseli (a.k.a. Johann Heinrich Fuessli). By a strange quirk of fate, Fuseli is interesting to a Unitarian audience because he had an affair with Mary Wollstonecraft, a famous voice from our radical tradition. But back to the engraving — it is of an even more famous voice from the Unitarian heritage: Joseph Priestley LL.D., FRS. The portrait shows a relatively young man sitting at a table covered with books and manuscripts; he holds himself erect and proud; he's evidently calm and confident in himself and his abilities. He looks to the right of the artist as if facing a protagonist in debate. This portrait was on the walls of my parents' home for as long as I can remember, and without quite knowing why I became aware that Joseph Priestley was a famous English Unitarian thinker and preacher, and that his place of honour in our home, a Unitarian manse, was secure. At school, I heard his name again, this time as the discoverer of "de-phlogisticated air" - what we now call *oxygen* - and I felt a boyish pride that a hero of our household should also be listed among the world's great scientists. Some identify Priestley as the father of chemistry. I would say that the conception of chemistry was a sordid business in which many men and more than a few women had a hand, though that's not to diminish the seminal role that Priestley played in this fundamental science! As a boy, the fact that Priestley's name came up in two apparently unrelated contexts impressed me, and I began to be dimly aware that liberal views in religion might go hand in hand with a particular attitude to everything: a questioning of all received wisdom and a dissent from unsupported authority in any sphere of activity. In other words, I began to feel that the exercise of reason wasn't limited to obvious topics like algebra and geometry, or chemistry and physics, but could be applied, if one was so inclined and could find a way to do it, to every aspect of human life.

The year 2004 is the 200th anniversary of Priestley's death, and it is appropriate that in the Essex Hall Lecture we mark the contribution of this great Unitarian to the intellectual development of our movement and the wider community. In this Lecture, I shall try to indicate with a broad brush the immense sweep of his achievements over a broad range of human endeavour. In a 50 year period Priestley produced over 250 books, pamphlets, articles and papers, as well as preaching and experimenting in his laboratory, so this survey of his work must necessarily be unsatisfactory and sketchy. Nevertheless, it is surely a delight for us now, in this age of specialization, to revel, as if by proxy, in the freedom of the Enlightenment age, when thinkers such as Priestley could regard all intellectual activity as their playground. It was an era when an educated person would try to keep abreast of all advances in the arts, philosophy, theology, and science. Sadly, such breadth is something that nowadays is not well regarded: we are expected to specialize; there's something suspicious about the generalist. There are, doubtless, many historians here who are better acquainted with all aspects of Priestley's life, and especially his development in theology, than I am. As a scientist, I am more concerned with what we can learn from his approach to problems and his modes of thought than any specific conclusions that he may have reached during his life. So what I plan to do in this talk is to give first a rapid survey of his life and achievements, and then use his life as a jumping-off point for speculation (always more interesting than fact, said Mark Twain). Why is Priestley important for us today? What was he trying to achieve? What were the successes for which he should be remembered? What can we learn from his life? Can we apply those lessons to our own times?

I am a scientist, an astronomer. Astronomy is a subject to which Priestley had, I believe, rather little exposure. As we shall see, Priestley became associated with the development of new sciences, the study of heat and energy, materials, chemistry and electricity; in fact, the sciences of the new industries powering the Industrial Revolution. But I imagine that he would have been fascinated by the modern developments in astronomy that involved the newer sciences he helped to develop. Therefore, in this Lecture I shall review briefly Priestley's life and work; I shall consider why he is an important figure for us today; I shall speculate that our human origins as revealed by modern science would have been a subject that Priestley himself would have explored in our modern age; and finally, I shall consider what lessons he might have drawn from modern science as to our present and future condition on Earth. Priestley believed strongly in the rationality of Christianity and the ever-improving conditions of humankind: he wrote "...we may expect to see the extinction of national prejudice and enmity, and the establishment of universal peace and goodwill among all nations...". He would, I am sure, be delighted with modern scientific advances that allow us to glimpse the future.

2. A brief review of Priestley's life and work

Education

Priestley was born in 1733 on March 13 (Old Style) or March 24 (on the Gregorian calendar from 1751) in Fieldhead, Birstall, six miles from the centre of Leeds. He was the eldest son of Jonas Priestley, a dresser and finisher of cloth. Many of the Priestley family connection worked in the clothing industry, and since at that time the work was largely carried out at home textile workers developed independence and a taste for liberty. The industry was the trigger for the Industrial Revolution, so Joseph was embedded in that great development from his birth. Joseph's arrival was followed rapidly by three brothers and two sisters; and his mother died when he was seven. Two years later, after his father re-married, Joseph went to live with his Aunt Sarah, Mrs John Keighly. Although a Calvinist, she opened her doors to every kind of dissenting minister "...and those who were the most obnoxious on account of their heresy were almost as welcome to her if she thought them good and honest men" he wrote later. This challenging environment must have influenced Joseph in developing his own independence. He was a truly exceptional boy: he learned Latin and Greek at school and Hebrew from a dissenting minister, and while recovering from an illness he taught himself French, Italian, and German. Another minister taught him algebra, geometry and Newtonian mechanics, while he studied Chaldean, Syric, and Arabic. His aim was to be a minister, initially as a Calvinist. But even at an early age he had begun a spiritual journey towards more liberal views; he had sought membership of a local congregation, but was denied because he could not accept the doctrine of original sin.

In 1752, aged 19, he entered the Daventry Academy (he was the first student of this newly opened institution), the ancient universities of Oxford and Cambridge being generally reserved for those who accepted the Thirty Nine Articles and were members of the Church of England. The dissenting academies were, in fact, a consequence of the 1662 ejection of two thousand ministers from their livings; many of those ministers took to teaching and founded liberal academies. Some of the academies offered instruction in science as well as the arts and theology. At Daventry, Priestley studied anatomy, astronomy, natural philosophy, chemistry, and mathematics. Some of the teaching was through the method of disputations, in which teachers and their assistants argued both sides of a case. It was a method that Priestley used effectively in later life. His religious position shifted further while he was at Daventry; he "saw reason to embrace what is generally called the heterodox side of almost every question".

Minister, Tutor, Scientist

After three years at Daventry Academy he left to take up the post of assistant minister at Needham Market, Suffolk where his heretical views were not appreciated, and his congregations dwindled — as did his salary. He survived only by charity. In spite of this his spiritual journey continued, and he rejected the doctrines of atonement and the Trinity, and refused to accept the divine inspiration of Scripture. He was successful in becoming minister at Nantwich (1758) where, fortunately, the members of his congregation were broadminded about his heresies. He started a school there, probably the first in which children actually carried out experiments with scientific apparatus. He wrote an *English Grammar* for his pupils in which he demonstrated grammatical errors with examples from Swift, Pope, Dryden, Sterne, Shakespeare, Johnson and Hume. It was a happy and successful period; he later wrote "that in no school was more business done, or with more satisfaction, than in this of mine". He must have been an inspiring teacher, for the school day was very long: from 7 am until 4 pm! Perhaps he was able to use humour positively; in his *Grammar*, he stressed the use of plain English to communicate well, and illustrated this with the couplet:

"Beneath this stone my wife doth lie
She's now at rest and so am I."

In 1761 he left Nantwich and took up an appointment as tutor in languages in the Dissenting Academy in Warrington. Priestley himself would have preferred to teach mathematics and natural philosophy. The Academy was designed for the education of young gentlemen for the learned professions or for business. It was open to all, without tests of race or creed, and attracted students not only from the British Isles but also from the colonies. Soon after moving to Warrington, Priestley married Mary Wilkinson; she was the daughter of the ironmaster Isaac Wilkinson who then gave generous financial support to Priestley. Wilkinson could afford to do so; he was an arms manufacturer who supplied the British army, and — it is rumoured — also supplied the French with artillery. It's not widely known that our hero was subsidised by the arms trade! We have become much more sensitive about such matters! Priestley was awarded the degree of Doctor of Laws (1764) by the University of Edinburgh for his *Chart of Biography* which he finished at Warrington. This was a wall chart, two feet by three, on which the names of about two thousand famous people in the period 1200 BC - 1800 AD were inscribed, to show the relationship between great men and their own times, and between predecessors and successors. Priestley emphasised science in his *Chart*: "By the several void spaces between the groups of great men we have a clear idea of the great revolution of all kinds of science". He was excited by the acceleration in the rate of scientific discovery: "What a figure must science make advancing as it does now, at the end of as many centuries as have elapsed since the Augustan age!" He concentrated on teaching languages, wrote various essays, in one of which he attacked the idea that education should be undertaken by the state, arguing that it was inimical to liberty and to the natural rights of parents. How times have changed! He set up a small laboratory of his own, arranged for lectures on chemistry to be added to the curriculum. He took an interest in electricity and began his own experiments.

In this period, he made regular trips to London from Warrington, and met in particular Richard Price, the dissenting minister and mathematician, and Benjamin Franklin, the scientist and philosopher. Franklin encouraged Priestley to write his *History of the present state of Electricity, with original experiments*, a massive tome which established the subject in its own right as a post-Newtonian science and formulated its development. The book reports experiments from which Priestley deduces that electrical charges of opposite sign obey the inverse square law of force (apparently pre-dating the law normally attributed to his contemporaries, Charles Coulomb, 1736 -1806 and Henry Cavendish, 1731 - 1810). His experiments earned his election to the Royal Society (1766), while his book was published a year later. Priestley wrote not only this huge book on electricity, but also on language, oratory, history, and an *Essay on a Course of Liberal Education for Civil and Active Life* in which he called for religious, intellectual and scientific subjects in a useful education. His colleagues at Warrington were like-minded in religion; evidently Priestley didn't spend long hours in theological discussion, and this allowed time for the flowering of his scientific and educational talents. But the Warrington Academy had financial problems, and the salaries for tutors were very low, so Priestley accepted (1767) a call to Mill Hill Chapel, Leeds to become once again a practising minister. He stayed six eventful years in the city of his birth, and wrote in this period some thirty works in which his attentions turned again to theology. His transition from Calvinism was complete, and he presented himself to Mill Hill as a Unitarian: "The Messiah was a man like ourselves; a man approved by God, neither unerring nor unblemished". Therefore, he rejected Christ worship as idolatrous. John Wesley adjudged him "one of the most dangerous enemies of Christianity", and Methodists sang the hymn

" Stretch out thy hands, thy Triune God
The Unitarian fiend expel
And chase his doctrine back to Hell."

His political views were also on the move, affected by events in North America and in France. In his *Essay on the First Principles of Government and on the Nature of Political, Civil and Religious Liberty* (1768) he described his optimistic belief that "human society approaches perfection and would achieve glorious and paradisiacal ends beyond imagination" (a belief that struggles to survive in our more cynical age). But his call for liberty, revolutionary at the time, is now the watchword of us all: "Let all the friends of liberty and human nature join to free the minds of men from the shackles of narrow and impolitic laws. Let us be free ourselves, and leave the blessings of freedom to our posterity."

Priestley's time in Leeds was, nevertheless, also vital for his scientific legacy. He lived next door to a brewery, and was drawn to making experiments in the layer of "fixed air" (we call it carbon dioxide, CO_2) that covered the surface of the brewing vat to a depth of a foot or so. Lighted candles were immediately extinguished in this gas. He found that the gas was readily soluble in water, producing a sparkling water indistinguishable from the spa waters that were regarded as having medicinal properties. Consequently, Priestley leapt to the conclusion his artificial sparkling water would also be a healthy drink, and might even prevent scurvy — a hope without the slightest foundation, as we know today. Nevertheless, the work was regarded as important, and won Priestley the Royal Society's Copley Medal. Fortunately, no one tried to solve the Navy's problem of scurvy with a fizzy drink! It was left to Gowland Hopkins in the 20th century to identify the lack of Vitamin C as the cause of scurvy. However, Captain Cook had recognised the importance of fresh fruit in sailors' diets as early as 1772, so that British sailors (and, by association, all Britons) are now called "limeys".

Librarian, Companion, Scientist

In spite of his totally specious speculations about carbonated water, it was this work that gave Priestley considerable prominence and led to the Board of Longitude's invitation, subsequently withdrawn, to join Captain Cook's second round-the-world voyage. It also drew the attention of Lord Shelburne (a.k.a. William Petty, Marquis of Landsdowne), a young wealthy Whig statesman, to the abilities of the scientist/dissenter, and in 1773 the forty-year-old Priestley left Leeds to become Shelburne's librarian, literary companion, and tutor to his two sons, for a salary of £250 pounds per annum and a house near Shelburne's mansion at Bowood in Wiltshire. This stately home is now open to the public, and it's a moving experience for any Unitarian and any chemist to see Priestley's laboratory laid out, as if in current use; it seems as if Priestley has just stepped out to give lessons to the Shelburne sons.

While in Shelburne's service (1773 - 1780) Priestley gave his greatest efforts to scientific and philosophical researches, particularly in the study of gases, or "airs" as they were then called. It's hard to put oneself in the position of a scientist in the 18th century; we have become used to the idea that many different kinds of gases exist. In Priestley's day it was recognised that the air we breathe was different from "fixed air" (the brewery gas, carbon dioxide) and from hydrogen (released when acids corrode metals), but how many different gases were there? Hadn't the Greeks defined the air we breathe and the water we drink as elements? Priestley showed that air is a mixture of gases, not an element. He identified oxygen (persisting in calling it "de-phlogisticated air") and many other new gases, including nitrous oxide (or "laughing gas"), ammonia, sulphur dioxide, hydrogen sulphide, carbon monoxide, hydrogen chloride, chlorine, and silicon tetrafluoride. He showed that water is composed of two gases, now called hydrogen and oxygen, in the proportions of two to one by volume; thus, water was not an element but a compound. He invented new ways of preparing gases and of performing experiments upon them. He used mice to test the respirability of "airs" and described how to care for them: "If the air be supposed to be noxious, it will be proper ... to keep hold of their tails, that they may be withdrawn as soon as they begin to show signs of uneasiness ...". In his most famous experiment, described in *Experiments and Observations on Different Kinds of Air* (1774), he used a 12 inch lens as a burning glass to concentrate sunlight and heat red oxide of mercury (he called it mercurius calcinatus). He obtained a new gas, his de-phlogisticated air or oxygen and the metal, mercury. Priestley wrongly assumed that the oxide of mercury was the pure element which, by the addition of the mysterious substance, phlogiston, is turned into a shiny metal. We know that the reverse is true: mercury is the pure element that can be combined with oxygen from the air to make mercury oxide (or mercurius calcinatus). He imagined the following reaction occurring under the action of heat:

mercurius calcinatus + phlogiston --> mercury metal + de-phlogisticated air

while we write, equivalently, but more accurately

mercury oxide + heat --> mercury + oxygen

which expresses the fact that heat energy breaks the chemical bonds between mercury and oxygen, giving the pure element mercury and the gas oxygen.

Priestley showed that a candle burned brightly in the new gas, and that a mouse survived in it. He found that the new gas was "between four and five times as good (i.e. for respirability) as common air". We know that the air we breathe is one fifth oxygen, the rest being mainly nitrogen, so his estimate was remarkably accurate. He himself breathed oxygen and "felt peculiarly light and easy for some time afterwards"; thus oxygen in the air had been absorbed in the lungs. (It's an interesting coincidence that our two Unitarian "saints", Servetus and Priestley, both had points to make – in passing - about respiration). He thought that oxygen might be useful in enhancing combustion in blast furnaces or for making explosives. He showed that green plants can restore the quality of air: a candle in a closed vessel eventually sputters out when it has used up all the oxygen; but if the closed vessel also contains living vegetation, then - with the aid of sunlight - the oxygen is restored and the air is breathable again. Therefore, Priestley discovered the process of *photosynthesis*, the means by which the respirability of Earth's air is restored. These ideas are, of course, of crucial modern importance: we are upsetting the balance of gases in the air of planet Earth, and this imbalance is driving global warming. We are putting carbon dioxide into the air faster than it can be removed by photosynthesis, so the amount of that gas in the air is increasing.

In 1774 Priestley travelled with Shelburne on a tour of Europe. In Paris he met the great French scientist Antoine Lavoisier (1743 – 1794) and other philosophers, and in his conversations with them did not hide his religious beliefs. They told him that "he was the only person they had ever met with, of whose understanding they had any opinion, who professed to believe Christianity". So Priestley wrote later his *Letters to a Philosophical Unbeliever* (published after his move to Birmingham) to educate the atheistic philosophers at home and abroad on the subject of Christianity. In spite of these efforts, he was heartily disapproved of by orthodox Christians who felt that his views, such as those that the soul was material (expressed in his *Disquisitions relative to Matter and Spirit* 1777), made him no better than an atheist; this materialist view of human life led to a mock epitaph being composed about him:

"Here lies at rest,
In oaken chest,
Together packed most nicely,
The bones and brains,
Flesh, blood and veins
And ***soul*** of Dr. Priestley."

His patron Shelburne was pressured to dissociate himself from Priestley. They parted amicably, though Priestley suffered financially and had to be supported by wealthy industrial benefactors (including Josiah Wedgwood).

Birmingham and the Lunar Society

His position was stabilised by a move north, to Birmingham, in 1780, when he was forty seven, as co-minister of the New Meeting congregation — "the most liberal of any in England" he said. It was at first a happy time. He joined that remarkable group, The Lunar Society of Birmingham — the "friends who made the future", as Jenny Uglow has so aptly put it: "They are a small informal group of men who simply try to meet at each other's houses on the Monday nearest the full moon, to have a light to ride home, and like other clubs they drink and laugh and argue into the night. But the Lunar men are different - together they nudge their whole society and culture over the threshold of the modern, tilting it irrevocably away from old patterns of life towards the world that we know today." Among these friends were Matthew Boulton, chief of the world's first great factory, and his partner, James Watt of the steam engine; Josiah Wedgwood was the pottery king, and Erasmus Darwin was doctor, inventor, poet, and pioneer of evolution half a century before his more famous grandson, Charles.

In fact, in spite of this stimulus, much of Priestley's scientific work was completed by this stage of his life, although he continued to publish results of earlier work. His energies were mainly spent on preaching (for which he had developed a conversational style to overcome his stammer), in campaigning against slavery (a brave action in a town that was an integral part of the slave trade), in writing on theology (in which he became extremely unorthodox and unpopular) and on politics (which finally brought his career in Birmingham to an end). Like the famous Unitarian, Servetus (1511 - 1553), Priestley had the simple-minded but evidently mistaken idea that pointing out errors in established church doctrine and identifying superstition would cause people to put a "purer" religion in its place. However, Priestley didn't suffer the supreme penalty delivered to Servetus by Calvin as a consequence of writing his book *Christianismi Restitutio* (or *Christianity Restored*). More than two centuries after Servetus was burned at the stake, Priestley's *History of the Corruptions of Christianity* (1782) was publicly burned by the hangman at Dordrecht in Holland; an insult and an irritation, indeed, but not terminal. No wonder those French stars of the Enlightenment rejected Christianity (though atheism was no protection — Lavoisier himself was put to death on trumped-up charges by the French Republic in 1794)! Priestley's *History of Early Opinions Concerning Jesus Christ* (1786) met with no better reception. His hopes that a pure original Christian religion extracted from the corrupt modern form would naturally attract adherents were, like Servetus' earlier attempts, doomed. But, as Alexander Gordon later remarked, Priestley's great contribution to theology was his method of analysis; the New Testament was to be regarded as a product of historical circumstances, not revealed truth. "What are the scriptures but the writings of men who are now dead?" he said. In his method of analysis, called by Gordon the historical method, Priestley was — it seems to me — simply applying the methods he used to study chemistry or electricity: he took an *empirical* approach to the evidence.

Opposition, expulsion, refuge in America

Already in trouble for his theology, his political views brought him down. The desire of Dissenters for civil liberty for all encouraged Priestley to make statements in support of the French Revolution, and these were interpreted as a threat to the British monarchy. Indeed, his views had become more extreme. He had abandoned his earlier support for King, Lords and Commons in favour of a "Unitarian" government: that "in every state as in every person there ought to be but one will" and that, of course, was the people's will. In his view, the Anglican Church now seemed a "fungus" upon the noble plant of Christianity. His frustration at Pitt's failure to relieve the Test Acts (that restricted the rights of nonconformists and Roman Catholics) caused him to sneer at Pitt's subservience to the bishops who, he said, were "recorded in all histories as the most jealous, the most timorous, and of course, the most vindictive of men". Priestley did not lack for enemies! He had offended both the powerful and the mob, and the end was inevitable. A dinner on 14 July 1791 (not attended by Priestley, but with about eighty persons present) to commemorate the second anniversary of the storming of the Bastille was the trigger; with the encouragement of the authorities a pro-Church and King mob held a rival meeting, but were too late to disrupt the dinner. In their fury and frustration they turned to Priestley's New Meeting House and to the Old Meeting House, and burned them both. Jenny Uglow writes: "The fire engines were slow (the Vicar of St Martin's had apparently ordered the key to their shed to be removed) and when they did come the crowd let them turn their hoses on neighbouring buildings but not on the meeting house itself." The mob then turned on Priestley's house, burning the library, destroying the laboratory and razing the house. The rioting continued for several days, and well-orchestrated violence destroyed four meeting houses and twenty seven houses.

Priestley watched the destruction, and then escaped to London. He received many condolences, including one from the French Academy of Sciences. However, neither the Royal Society nor the Manchester Literary and Philosophical Society sent any message. Priestley wasn't surprised. "Had I been a second Newton and an Unitarian Dissenter, my expectation from that quarter would not have been higher." He succeeded Dr Price as Dissenting Minister at Hackney, but feeling that he could not hope to give his sons a good start in life in England, decided in 1794 to emigrate to America; surely not an easy decision at the age of 61. He settled in Northumberland, a five-day journey through the wilderness from Philadelphia. He built a house, installed his library, conducted experiments, and tried to maintain his contacts with the wider world through correspondence. His son Henry died soon after his arrival, as did his wife Mary. His own health began to fail in 1801, and he died on February 6, 1804 with his son Joseph at his side. His last act was to edit his writings on Socrates and Jesus. When this was completed, he said: "That is right; I have now done" and died shortly afterwards.

3. Priestley's achievements and their importance to modern rational dissenters: what can we learn from his life?

J G Crowther wrote in 1962: "His (Priestley's) courage and candour shine with an enhanced brilliance against the modern background of calculated expression and manipulated opinion." In retrospect from our present era of the 21st century, the 1960s seem now to be a period of honesty and openness, when the post-war rigidities were being questioned by a radical young generation who rejected authority and sought their own answers. In contrast, the 21st century seems to have begun in cynicism, distrust, and frustration. We seem not to have a clear vision of our future, neither of its pleasures nor of its responsibilities; we seem to be confused and uncertain about the true issues facing our world. Do not, therefore, Priestley's courage and candour shine with even greater brilliance against the contemporary background than in Crowther's day? I believe that they do.

In this section, I am simply going to list those achievements and characteristics of Priestley's life that strike me as important for religious liberals and dissenters of today.

- He believed that **rational thought** could and should be applied to all aspects of life; he believed that a "pure" Christianity cleansed of superstition by rationality would ultimately succeed.

- He was **tolerant** of the views of others; he campaigned for the rights of Roman Catholics, Calvinists, and others just as powerfully as he did for liberal dissenters.

- He was **intolerant of injustice**; he campaigned against slavery in Birmingham, a city embedded in the slave trade. He was disputatious in favour of justice.

- He believed that science, religion and the arts were not separate endeavours; he took an **holistic view of human activity** (as did Servetus before him): he saw science as the exploration of the complexity of creation, and therefore a religious activity.

- He made an immense **spiritual journey**, from Calvinism to Unitarianism; today, in our liberal religion, we recognise that we are all to a greater or lesser extent making our own individual journeys.

- He had a **passion for truth** in all his works, yet showed his human limitations in the political naivety that led to his downfall, and in the (rather endearing) "blind spot" that prevented him from recognising the true significance of his own discovery of oxygen.

- He was the principal English figure in the European movement known as the **Enlightenment**; he and his Lunar Society colleagues broadened the Enlightenment movement from purely philosophical to practical, and began the irreversible transformation of our society from agrarian to industrial.

- He was a powerful and successful **educator**, introducing novel ideas into the classroom and starting the first Sunday School for nonconformists. He began the tradition of Unitarian involvement in liberal education for boys and girls.

- In spite of many reverses, he had **optimism** for the future development of society in spite of its political and religious differences.

- He ultimately became a democrat at a time when **democracy** was a dangerous and treasonable concept.

In science, his achievements were wide-ranging and influential:

- He conducted **fundamental experiments on electricity**, introduced the idea of the inverse square law of force of attraction between unlike charges (known now as Coulomb's Law), and corresponded with the young Michael Faraday who extended his work and was to lay the foundation of our electrically-powered civilization.

- He discovered **a variety of "airs"**; i.e. he showed that many different kinds of gases exist. One of these gases, nitrous oxide, was later found by Humphry Davy, with whom Priestley corresponded, to have anaesthetic properties. His work also influenced directly many other great scientists, including Dalton and Henry.

- He **isolated oxygen**, showed that it was part of the air that we breathe, and so showed that the air is a mixture of gases and therefore not an element. He demonstrated that oxygen is taken up by blood in the lungs.

- He showed that **water is a compound of hydrogen and oxygen**, in the proportions of two volumes to one; therefore water is not an element.

- He was the first to demonstrate and describe **photosynthesis**, the process by which our atmosphere is regenerated by living plants and sunlight.

- He and others swung the emphasis of British science away from Newtonian physics and towards the **new sciences of chemistry, materials, heat and energy**; these were the sciences that were relevant to the technologies of the age.

- He epitomised **the Industrial Revolution**: he was born into a family of domestic industry, sought to apply the results of his science to the technologies of the day, and associated with the men driving the great new industrial enterprises.

We cannot hope to emulate his achievements but we can try to copy his estimable qualities, and learn lessons from his life. As Gibbs has noted: "He belongs not only to England and the eighteenth century, but to the world and the generations yet to come who will respond fearlessly to the promptings of reason and conscience." Yet for all his achievements and in spite of his bitter enemies, he was a gentle and much loved person. A contemporary account says "He was the most unassuming candid man I ever knew, and never did I hear from his lips one illiberal statement or one harsh expression concerning any persons who differed from him, not even of the individuals who were so much in the practice of abusing him and traducing his character."

4. Our human origins revealed by chemistry

Part of the fascination that Priestley holds for me is that he stands as a symbol of rational dissent, as one who made a courageous spiritual journey; and part lies in his role as a scientist, first in physics and then in chemistry. He demonstrated rational dissent in science, as well as in theology and politics. Without benefit of formal teaching, simply by the power of his own intellect and technical skill, he designed and conducted experiments and interpreted their results in such a way as to place himself at the forefront of science. His experiments are elegant, convincing, and repeatable. Through them, he answered questions that others had not yet thought to ask; for example: how is it that although a mouse will eventually asphyxiate in a closed volume of air, the air we all breathe remains fresh and supports the life of uncounted millions of human beings and other animals on planet Earth?

What would Priestley have achieved had he lived in the modern era? If he had received a broad education in science and the arts and had access to the intellectual riches in our libraries and on the internet, in which direction would his interests have taken him? As a theologian and philosopher he would, I am sure, have made a spiritual journey equally as dramatic as his move from Calvinism to Unitarianism, but we can only guess what would have been his final position. In science, he would surely have revelled in the wealth of knowledge available to us.

I like to think that he, as a co-founder of the subject of chemistry, and as a philosopher who pursued science as a demonstration of the richness of creation, would be particularly intrigued by the modern role that chemistry plays in helping us to understand the place of humanity in the Universe. This is a new and quite rapidly developing story. It is a successful application of Priestley's subject – chemistry. It is an area in which chemistry and astronomy combine to form a new subject: astrochemistry.

Astronomy in the 18th Century

Priestley didn't have much exposure to astronomy. It would have been taught to him as a pupil in Daventry, and to the scholars in Warrington Academy by his colleagues on the staff there. Had he (as originally invited) joined Captain Cook's second round-the-world voyage as astronomer/botanist he would, no doubt, have become proficient in both subjects. But the kind of astronomy practised on such a voyage — sometimes called mercantile astronomy — was essentially related to navigation. The period of Priestley's life coincided with the period in which the problem of accurate navigation was being addressed. Dava Sobel in her book *Longitude* has reminded us of the dreadful cost of poor navigation; she relates the story of Admiral Sir Clowdisley Shovell in 1707 guiding his fleet returning to England from Gibraltar directly on to the Scilly Isles, rather than — as he thought — safely around the coast of Brittany. Two thousand sailors died on those rocky shores off the Scillies. The shock of such a disaster, especially one happening close to home, encouraged Parliament to offer a prize for the accurate determination of longitude of a ship at sea. The growth of trade and empire demanded accurate navigation. Knowing the latitude (i.e. North-South movement) of a ship's position was easy, but longitude (East-West movement) required a comparison of time at noon of the ship's position with noon at the starting point of the voyage. Astronomers and clock makers competed for this prize; astronomers said that the most accurate clocks are the motions of planets, moons and stars, but unfortunately the skies are often obscured by clouds. Nevertheless, astronomy was dominated by studying systems (like Earth's Moon or Jupiter's moons) that could be used for Earthly clocks. Dava Sobel reminded us that it was the lowly clock maker, John Harrison, who — after a lifetime of cruel and corrupt opposition from a Board dominated by gentlemen astronomers — finally won this competition. Harrison's achievement was finally recognised by the Board of Longitude in 1773. He died only three years later, at the age of eighty six.

Therefore, much of astronomy during Priestley's life was related to navigation, rather than the science that describes the Universe, as we know it today. It was William Herschel (1738 - 1822), musician and astronomer, who began to change all that, first with his discovery in 1781 of the planet Uranus, but – more importantly – through the surveys of the heavens made with his sister Caroline in which a great variety of different kinds of objects were discovered. Herschel promoted the idea, originally put forward by Thomas Wright (1711 - 1786) that the stars are arranged in a disk, what we now call the Milky Way Galaxy, one of uncounted other galaxies.

Astrochemistry – the Priestley connection

Where does chemistry come into this? Why might Priestley be interested? Over the last few decades it has become clear that the space between the stars, interstellar space, isn't empty, but contains clouds of gas and dust. This interstellar gas is made up of a variety of molecular species, including those molecules that Priestley himself isolated experimentally on Earth: carbon monoxide (CO), ammonia (NH_3), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S) among them. In fact, the chemical complexity is very much greater than this list implies, and astronomers have now identified more than 120 different types of molecules in interstellar clouds. From a chemical point of view, this is fascinating, and Priestley would, I am sure, have found it so. He would have asked, as astronomers do now: how are these molecules made in the harsh conditions of interstellar space? There, the gas pressure is lower than that in the best vacuum that we can make in earthly laboratories, and the temperature is about 260 degrees Celsius below the freezing point of water. Is the chemistry that gives rise to these molecules different in some fundamental way from the chemistry with which we are familiar here on Earth, for which Priestley's early experiments were our guide? These questions have triggered a huge effort from chemists, physicists, and astronomers over the last thirty years. We now understand the situation fairly well; we know pretty accurately how the molecules are formed and destroyed. I think that Priestley would have been delighted that the molecular species that he was able to isolate in his experiments exist also in the heavens, and are present there in unimaginably large quantities. I am sure that he would have been fascinated by the intellectual challenge presented by the astronomical observations and by the solutions that have been put forward on the basis of elegant laboratory experiments. But it isn't simply an interesting but empty intellectual exercise; this work has shown a result of fundamental importance: chemistry and physics as we understand them on Earth are truly Universal. Results obtained in experiments on the microscopic nature of matter, such as those in Priestley's laboratory, apply in our Milky Way and other galaxies. Therefore, the Earth isn't different from the rest of the Universe; it obeys the same scientific laws as everywhere else, and is part — albeit a very tiny part indeed — of the Universe. Priestley would, I am sure, be delighted with this demonstration.

Stars and planets

From an astronomical point of view the discovery of interstellar molecules has had enormous consequences. Firstly, radio emission from the molecules, particularly Priestley's molecule carbon monoxide (CO), allows astronomers to trace the presence of gas clouds in interstellar space. We find that in our own galaxy, and in many others, there are huge reservoirs of gas, previously unrecognised, in the form of clouds, and that some of these clouds are the biggest structures in those galaxies, more massive than clusters of stars containing hundreds of thousands of stars. Secondly, astronomers find that very young stars are generally associated with these clouds, and therefore conclude that the stars and their planets form from this gas. Thirdly, in fact, the association is so close that one can see stars forming! Star formation isn't a process that is already completed, it's happening now; we live in an ever-changing Universe. We can detect the formation of clumps in the gas, and their contraction under their own weight, as they begin to condense to form stars. Fourthly, the energy in the radiation that we use to trace the presence of the molecules is a serious energy loss for those clumps; in fact, were it not for that energy loss, the contracting clumps would become hot; their pressures would increase and terminate the contraction. So the emission from the molecules (especially from Priestley's molecules of CO and H_2O) is essential for the formation of stars and planets to occur in the modern Universe. Finally, planets are formed as a by-product of star formation. Contraction of a rotating clump in the early stages of star formation throws out a disk of gas and dust around the forming star, in the same way that a chef will spin a ball of dough to create a thin disk for a pizza. The accumulation of dust grains and gas from this disk into larger and larger objects eventually forms the planets. So the chemical composition of the initial interstellar cloud in which stars and planets are forming determines the chemical composition of stars and planets in that cloud. The chemical composition of the Earth — how much carbon, nitrogen, oxygen, hydrogen, phosphorus, and so on — and therefore our own human chemical make up, was determined by the chemical composition of an interstellar cloud that collapsed some 5000 million years ago to form a star, our Sun, and its attendant planets. Priestley would accept the rational arguments that establish this view of Creation, and would recognise the Genesis stories as poetic myths.

Astronomers can now observe a number of objects in various stages of collapse from interstellar gas to stars. At each stage, molecules such as carbon monoxide play a vital role in emitting energy from the gas and keeping it cool until the very final stages. This maintains the collapse from very tenuous gas to a dense pre-stellar object that is very tightly bound by its own gravity. Priestley would surely be intrigued to learn of the role of molecules that he had discovered in his laboratory in the grander experiments that Nature conducts in our Milky Way Galaxy and in other galaxies in the formation of stars, planets, and their inhabitants.

The picture is of interstellar clouds as a reservoir of matter from which new stars and planets are formed. But the reservoirs are — at least to some extent — being topped up, just as small streams and rivers top up our water reservoirs on Earth. The reservoirs in space are replenished and enriched by matter being ejected from stars. The Sun, we know, has a wind that rushes past the Earth, sometimes causing electrical storms that knock out our electrical power networks. Other stars have much more massive winds, and some stars explode violently in novae and in supernovae. All these stars eject the ashes of their burning into interstellar space. Stars are powered by continuous processes like those that occur briefly in a hydrogen bomb; those processes turn hydrogen into heavier elements, such as helium, oxygen, carbon and nitrogen. It is these elements, the "ashes" of the nuclear "burning" that powers the stars, that are ejected in stellar explosions and winds. Our planet Earth and our human bodies are made of these and other elements: this is the evidence that the matter of which our bodies are composed was once inside a star, ejected into interstellar space, mixed with and enriched the gas, and accumulated into clouds from which new stars form. In particular, the cloud that formed our Sun and its planets was certainly enriched by the ashes of a nearby star ejected in a supernova explosion. There is, therefore, a cycle of material between stars and clouds, the clouds gradually diminishing in mass as the stars and planets form within them, the gas in the clouds becoming all the time more and more enriched in carbon, nitrogen and oxygen, and other elements.

The process of planet-building was violent. The growth of tiny dust grains occurred by gradual accumulation into larger and larger units. The larger pieces collided and stuck to each other, eventually forming proto-planets that continued to be bombarded with smaller debris. To some extent, the process continues still, so we must accept the evidence in front of us. The Earth accretes hundreds of tonnes of dust each year; the dust grains are caught by Earth's gravity and drift slowly down through Earth's atmosphere. Bodies of a few metres in diameter collide with Earth every month or two, and are burned up in the upper atmosphere, appearing as a fireball. Every century or so, objects a hundred metres across crash on to the Earth's surface with a huge release of energy, creating a crater on land or a tsunami in the ocean. Perhaps once in a million years a truly massive object, several kilometres across, impacts on the Earth and causes a global catastrophe, such as the demise of the dinosaurs. We live in a shooting gallery. Fortunately, the intensity of the cross-fire is much less than it used to be when the planets were forming, but the evidence for planet building by collisions is everywhere — most obviously on our neighbour the Moon, but also on Earth and other planets.

Planet Earth and life

In general terms, astronomers understand how our home, planet Earth, was formed some 4.5 billion years ago. The fossil record tells us something about the emergence of life on Earth, though we are very far from understanding the chemistry that introduced biology to Earth. Primitive micro-organisms appeared on Earth about 3.5 billion years ago, as soon as the surface had cooled sufficiently for them to survive. In chemical terms, this was a huge and — so far — unexplained step in complexity. After about another one billion years, simple plants like algae appeared, and — very slowly — more and more complex forms of life arose. During this immense period of time, these plants used sunlight to convert the carbon dioxide in the atmosphere to oxygen, in the photosynthesis process originally described by Priestley. Could he ever have imagined that this process was responsible not only for maintaining the atmosphere that we now breathe but also for establishing it in the first place? That is what happened; the CO_2 rich primitive atmosphere (like that on Mars today) became the oxygen-bearing air on which we now depend. Air breathing animals became a possibility, and are found in the fossil record from about 600 million years ago. The large lizards, the dinosaurs, ranged the Earth from about 250 to 65 million years ago, and then came the age of mammals. The precursors to *Homo Sapiens*, our species, appeared almost 10 million years ago.

Priestley would have been aware of the work of his near contemporary, James Hutton (1726 – 1797), whose *Theory of the Earth* (1785) laid the foundations for a new subject, geology. Priestley would have learned from Hutton's work of the huge intervals of time necessary for the continual development of the Earth and for the emergence of life. Perhaps the enormous duration of the Earth, described above, and the huge intervals of time required for Earth's development would not have surprised him, even though they are very much larger than Hutton would have envisaged.

But the numbers are indeed hard to appreciate! Let's imagine that the period from the formation of the Earth until the present is represented by one year; the Earth is then formed on January 1. Then simple life appeared at the end of February, simple plants by mid-May, and air-breathing animals by mid-October. The era of the dinosaurs lasted from early to late November, and the age of mammals then began. Hominids appeared at 5 am on December 31, and Priestley died at 1.4 seconds before the end of the year. Thus, the Industrial Revolution, which occupies the period since Priestley's day, is really tiny on the scale of Earth's history. Yet in that brief period, human activities have begun to modify Earth's climate, with serious consequences for our civilization.

Priestley was certainly aware of the work of his contemporary, William Herschel, in mapping the skies. He was also familiar with Newton's interpretation of the solar system based on gravitation. Priestley would have assumed, as we do, that other planetary systems exist around other stars. He would, I am sure, have asked himself that essentially religious question that we all pose: does life exist elsewhere, on other planets orbiting other stars? Are we alone in this Universe? The answer to this question has until recently been entirely speculative. But now modern astronomy allows us to address at least part of it, and ask: are there really planets outside the solar system? If so, what are they like?

Are we alone in the Universe?

Astronomers have been able to detect indirectly the presence of over one hundred extra-solar planets, i.e. planets orbiting stars other than the Sun. The planets aren't imaged directly; the detection is made because the planet tugs the star to and fro as it completes its orbit, and it is the small but regular changes in the star's velocity that are the signature of the planet. Naturally, the larger the planet and the closer it is to the star, the greater is the tug exerted on the star. Therefore, this method selects the most massive and closely orbiting planets. So the list of detected extra-solar planets contains really massive planets, at least as massive as Jupiter (which has a mass about 318 times that of Earth), and some are about 50 times the mass of Jupiter. Such planets are essentially gaseous, and generally considered to be unsuitable for life. However, these methods don't rule out the existence of Earth-like planets; on the contrary, they do confirm that planet-building is a common feature in the Galaxy; so that we suspect that many Earth-like planets exist in orbits around stars other than the Sun. It's likely that the next generation of telescopes, operating in the next decade, will enable us to detect Earth-like planets. New detection methods are also possible. Since life as we know it implies photosynthesis, the process first described by Priestley in which living plants in sunlight breathe in carbon dioxide and breathe out oxygen, a detection of an oxygen-rich planet would be pretty convincing evidence for life outside the solar system. Such a planet might well be Earth-like, with a solid surface and possibly oceans. If he were here today, Priestley would certainly appreciate the significance of detecting oxygen on an extra-solar planet. He would recognise it as the indisputable signature of life. Of course, such a detection wouldn't tell us whether life had evolved beyond the stage of algae. To assess that, we would need to listen to the equivalent of the Radio 4 programme *The Archers*! The signal of our *Archers* programme is now reaching about fifty light years from Earth, i.e. this radio signal has been travelling at the speed of light away from Earth for fifty years. What will other civilizations, if they exist and are listening, make of that or of any of our radio and TV programmes? In fact, there is just such a listening search being conducted now on Earth, called SETI, the Search for Extra-Terrestrial Life. So far, no detections of radio emissions from other civilizations have been made. It is possible that other extra-terrestrial civilizations consider it safer not to advertise their presence by broadcasting radio and TV!

One can estimate the number of planets in our Galaxy that might have a civilization as least as technologically capable as ours. Obviously, this number depends on the rate at which stars are formed, the fraction of stars that have planets, and the fraction of those planets that are suitable for life. Astronomy can help us to determine these three factors. But there are other factors to be considered. Does life actually arise on a suitable planet? Our knowledge of the Earth might suggest that it does. If life does begin, does it remain at the primitive stages, or evolve to more complex forms? The evidence from the Earth is equivocal on this point, since the Earth clearly has only had complex life forms for a tiny part of its history. Once a technological civilization has arisen, is it stable, or does the society blow itself up in a nuclear war? The jury is still out on that question! If you make pessimistic assumptions, then you are likely to conclude that ours is the only advanced civilization in the Galaxy. More optimistic estimates suggest that the number of extra-terrestrial civilizations is large, and the SETI search is based on this assumption. However, there's little possibility of visiting or communicating with these civilizations, if they exist. The Galaxy is so big that even "phoning" our nearest neighbours (if we knew where they were) would mean waiting at least a thousand years for a reply. We would certainly have lost interest in the reply to any question we might have sent. All we can do is listen to messages (if any) sent out long ago. But we won't know if the senders are still in existence.

5. Priestley's message for us today

Priestley was motivated to study science as an exploration of the Creation. Our modern motivation may be expressed in different words, but amounts to much the same thing: the curiosity we feel about the Universe in which we live is quite compelling. The quest of exploration of the Universe and the matter of which it is composed is essentially a religious endeavour, requiring energy, commitment, and – most of all – imagination. I have no doubt that Priestley would have considered it important from a religious standpoint to address questions such as: are we alone in the Universe? He would surely understand the value of the fundamental work in chemistry that he carried out in providing the foundations of this curiosity-driven research.

Priestley and superstition

Much of Priestley's energies were spent in trying to remove superstition from religion; a "pure" Christianity, he felt, would be irresistible. I believe that he would be amazed and saddened at the extent to which superstition remains embedded in our society, in this supposedly rational age of universal education. He would surely be astounded that our society should reject the lessons of the Enlightenment. Priestley's friend, Benjamin Franklin, wrote to him in 1780: "The rapid progress true science makes occasions my regretting sometimes that I was born too soon. It is impossible to imagine the height to which may be carried in a thousand years the power of man over matter." These were views that Priestley himself also held.

Priestley would surely reject many aspects of modern society that are commonly accepted today, and would argue against them: astrology, psychic powers, magic crystals and pyramids, so-called New Age thinking, ley lines, feng-shui, communication with spirits, aliens from outer space, creationism, and much other clap-trap – all the "mumbo-jumbo – delusions of the modern world" as Francis Wheen calls it. Priestley would recognise that, in the words of Carl Sagan, "science is a candle in the dark of this demon-haunted world". He would wonder at our loss of confidence. He would wonder, for example, how it is that a British Prime Minister whose mantra is "education, education, education" could state in Parliament that the diversity of education supplied by those who teach creationism alongside modern biology was a desirable diversity. He would be saddened that George W. Bush has similarly been unable to resist the pressure from voters in favour of the superstition of creationism. Priestley would have been horrified, I feel, that practitioners of astrology and New Age healing have had access to the White House under various administrations, and also through Cherie Blair to Downing Street. Perhaps these visits don't really have significance, but these are — after all — the places where the destiny of our civilization is decided.

Wheen ends his fine book on our modern attitude to the Enlightenment with the following paragraph, which – I feel – might well have been written by a time-travelling Priestley: "Truth is great and will prevail. Or, to quote the tougher formulation of the Spanish-American George Santayana, 'The truth is cruel, but it can be loved, and it makes free those who have loved it.' Visitors to the US Archives building in Washington DC can read another of Santayana's epigrams chiselled over the main entrance: 'Those who cannot remember the past are condemned to repeat it.' He described this as the condition of 'children and barbarians, in which instinct has learned nothing from experience'. But those who refuse to learn from experience, and strive instead to discredit the rationalism that makes such enlightenment possible — whether they be holy warriors, anti-scientific relativists, economic fundamentalists, radical post-modernists, New Age mystics or latter day Chicken Lickens — are not only condemning themselves to repeat the past. They wish to confine us all to a life in darkness."

We must work, as Priestley did, for an enlightened life.

Priestley and the environment

Priestley was very much concerned with the world in which he lived and worked; the inter-relations between science and religion and politics were obvious and natural to him. I believe that were he present in our modern age he would be concerned about our environment and the damage wrought on it by the very Industrial Revolution that he promoted. Yes, we know that burning coal and oil is filling our atmosphere with carbon dioxide at a faster rate than photosynthesis can remove it. Priestley would have understood this perfectly, since he was the first to consider the question of maintaining the purity of our atmosphere; and he was the first to come up with the answer. Further, we know that the additional carbon dioxide in our atmosphere is causing an additional warming of the atmosphere, as the heat generated by sunlight is trapped more effectively by this extra CO_2. We know this, Priestley would understand it, but President George W Bush will not admit it and takes no action at all, because the oil companies are so politically powerful and it seems that he is in their thrall. I'm sure that Priestley would recognise the issue, and would not opt out of the responsibility for that damage to our planet, as some modern day campaigners do. It isn't possible to turn back the clock and live again as peasants in a pre-industrial era. Priestley would recognise this. He would see that being anti-science isn't an option; that damage on the environment created by human actions requires human intervention and correction. He would want to create a society that can live more harmoniously in its environment. He would accept that a problem exists and that a solution can and will be found.

Priestley and truth

Priestley had a passion for the truth. He would, I believe, have been disgusted with post-modern deconstructionism that denies the existence of reality or certainty, and which dismisses value-judgements. Priestley believed in the truth of his experiments and his careful analysis of ancient texts. He would surely argue: it is a *fact* that water is a compound of hydrogen and oxygen; it is a *fact* that plants convert carbon dioxide to oxygen; it is a *fact* that positive and negative electrical charges attract each other with a force that varies as the inverse square of the distance between them. He would say that there can be no question about the validity of these statements, nor of the reality to which they apply. He would surely deplore the lack of clarity in post-modernist writing, the concept of relativism in truth and in existence (relativism is the idea that neither truth nor reality is absolute) and he would have deplored and been offended by the deconstructionist idea that rationality is a form of oppression. Well, perhaps deconstructionism is merely a foolish fashion that will pass, a storm in an academic philosopher's tea-cup. But one might argue that the false notion that truth is somehow a variable quantity is one that politicians have adopted for their own benefit. We have become familiar, as Priestley would also have been, with the way that truth is economically meted out by those in control. He would, perhaps, be disappointed, even angry (as we also may be) that governments are permitted to manipulate the truth to their own advantage. Our greater scientific and technical knowledge has merely given greater powers of control over information; there has been no improvement in our moral sense. Information control is now both a weapon used in war abroad and routinely against populations at home. Priestley would not accept such a situation.

Our task

The message that I take from Priestley's life and work is that we have to understand our Universe in all its aspects. We have a beautiful and fertile world in which to live. It may well be the only such world in our Galaxy; we should certainly behave as if it is. We should take care of it, take responsibility for it. Priestley sought the truth by expressing rational dissent from the prevailing religious, political and scientific views of his time. Our responsibility is to seek the truth through our rational dissent from damage-causing actions of our society, and so to take responsibility for our tiny world. If we behave rationally, there are very few problems that we cannot overcome. Priestley is an example to us all to engage life to the full, to show a passion for the truth, and to engage in rational dissent from authority to attain these ends.

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