constructed theories that are completely symmetrical in their description of fermions and bosons. Indeed these 'SUSY' theories admit symmetry operations taking fermions into bosons and *vice versa*. The analogy is with the even and odd numbers that are taken into one other by the addition or subtraction of unity. The currently most successful attempts to combine Einstein's General Relativity with Quantum Mechanics make essential use of SUSY. The gravitational interaction of Newton has its own massless boson, the *graviton*, which carries two units of spin. Supersymmetry dictates that the graviton has a massless fermionic partner, the *gravitino*, with one and a half units of spin. This gives a theory called *Supergravity*, and the graviton and gravitino may be regarded as some of the vibrations of the current Lucasian Professor Michael Green's *Super String Theory*. Both are under intense investigation by the College's several theoretical physicists in the Department of Applied Mathematics and Theoretical Physics (DAMTP). The discovery of evidence for supersymmetry at the LHC would clearly give these studies a tremendous boost and possibly lead to the Final Theory: a complete account of all four fundamental interactions.

In other words, we are all hoping that 'we ain't seen nothing yet'.

Dickens and Science by Julian Hunt (1960)

The common view

Like others, when I first read Charles Dickens's novels, *David Copperfield*, *The Pickwick Papers*, *Great Expectations*, and *Hard Times*, I was bowled over by their great characters and their adventures in their vividly described Victorian milieux of school and business, law and and crime, on the beach at Yarmouth or in London's foggy streets. Everyone has their own reactions and maybe learns different lessons; I laughed a lot, to the annoyance of my wife, as I took many weeks slowly reading of *Dombey & Sons* amid the changing scenes of North London and the arrival of the railways. My cautious approach to finance has probably benefited from Mr Micawber's advice that if one's income only just exceeds expenditure that leads to happiness, but if otherwise then misery. But I did not think I was reading novels written by someone with a deep appreciation of science and its wider intellectual and cultural connections.

Like most readers I generally thought of Dickens as being highly critical of the social and environmental consequences of the scientific and industrial revolutions of the nineteenth century. This was the moral aspect of his novels that the literary critic F R Leavis so much admired. His descriptions of the polluted atmosphere and rivers – the Great Stink – and their effects on people's health are even known to politicians, as the leader of the Green Party in the House of Commons, Caroline Lucas, recently reminded readers of *The Guardian*.

A reassessment

My view of Dickens's interest in science changed completely when I read his last novel *Our Mutual Friend*, published in 1865, which revealed his considerable knowledge of the great developments in science and how these had become part of ordinary people's understanding of the world around them, although this point has been missed by most critics of Dickens's writing as well as by his biographers. Dickens had written about science over many years in the magazines that he edited, *Household Words* and *All the Year Round*. These covered current affairs from politics to railways, and even science policy. Dickens's general view of science, which most journalists and politicians share today, was that there would be greater progress even at a technical level, if science were explained better to the public and indeed to other scientists. His more profound and ambitious objective, in which he preceded Henri Poincaré's *Science & Method* by fifty years, was that science should inform the public so effectively that it would enable those who became interested in science to explore for themselves the wider implications of scientific ideas. This, he argued, would lead to a deeper appreciation and, to use the modern idiom, a greater public involvement in scientific issues.

Dickens put these ideas into practice through his literature, by surreptitiously popularising science as he wove the latest observations and even theories into the plots of his very human and apparently 'unscientific' novels. In at least one case, like other writers before and after him, by generalising certain ideas then current, he even proposed an important scientific concept before it had been considered in the scientific literature!

Satire and praise

At the same time Dickens poked fun at scientists and their supporters – but no more than he did in all his books with respect to every professional and business character. In *Hard Times*, written in 1851, he ridiculed the standard school-masterly view of science as being a matter of 'stick to facts Sir – rout out everything else'. He mocked the amateur scientists who met at the Pickwick Club, driven ostensibly by pure curiosity, in order to consider 'speculations on the source of the Hampstead Ponds with some observations on the theory of tittle bats'. This was a gentle satire on the British Association for the Advancement of Science, which was set up in 1836 to popularise science and its applications. In *Our Mutual Friend* the gloomy wine waiter who, at a dinner party, pours out a dodgy Chablis – apparently a common problem then – is compared to an Analytical Chemist, saying under his breath 'you wouldn't drink this if you knew what it is made of.' In Dickens's view any scientist in the City was also suspect, forming dubious companies like Collapse, Vortex, Docket & Company. He obviously had high-tech fluid dynamicists in mind.

But when it came to individual scientists Dickens wrote admiringly about them in his essays, particularly those whose work he used in his novels. John Dalton of Manchester, famous for his discoveries in chemistry, also wrote on meteorology. Dickens reviewed the latter in one of his essays, and meteorology then appeared again in *Oliver Twist* – in the wintry scenes of snow blown about in extraordinary patterns by the wind. Dickens also learned of the fearsome ocean waves experienced by the transatlantic travellers in *Martin Chuzzlewit* from the pioneer American Navy oceanographer and meteorologist, Lieutenant Maury:

> countless miles of angry space roll the long heaving billows. . . a boiling heap of rushing water . . . mad return of wave on wave, . . ending in a spouting-up of foam that whitens the black night; incessant change of place, and form, and hue; . . . louder howls the wind, and . . . the wild cry goes forth upon the storm 'A ship!'

Artist and naturalist

The science in Dickens's novels usually connects nature with people and animals. In the opening page of *Bleak House* (1852) one reads a naturalist's notebook transformed into art:

> Fog everywhere. Fog up the river, where it flows among green aits and meadows; fog down the river, where it rolls defiled among the tiers of

> shipping, and the waterside pollutions of a great (and dirty) city. . . Fog creeping into the cabooses of collier-brigs; . . .Fog in the eyes and throats of ancient Greenwich pensioners, wheezing by the firesides of their wards; fog in the stem and bowl of the afternoon pipe of the wrathful skipper, down in his close cabin; fog cruelly pinching the toes and fingers of his shivering little 'prentice boy on deck. Chance people on the bridges peeping over the parapets into a nether sky of fog, . . . as if they were up in a balloon, and hanging in the misty clouds.

One is reminded of Oscar Wilde writing in 1889: only artists enabled people to 'see fogs, not because there are fogs, but because poets and painters have taught them the mysterious loveliness of such effects. There may have been fogs for centuries in London. But . . . they did not exist till Art had invented them.'

Of Darwin and Kelvin

But no Oscar Wilde could have conjured up the extraordinary geological perspective that Dickens used, in the same passage in *Bleak House*, to deepen the mysterious gloom of the London scene:

> As much mud in the street as if the waters had but newly retired from the face of earth, and it would not be wonderful to meet a Megalosaurus, forty feet long or so waddling like an elephantine lizard up Holborn Hill. Smoke lowering down from chimney-pots, making a soft black drizzle, with flakes of soot in it as big as full-grown snow-flakes – gone into mourning, one might imagine, for death of the sun.

Dickens's last novel *Our Mutual Friend* (1865), was written after Darwin's *Origin of Species* had been published in 1859. The great developments in classical physics and mathematics across Europe were also publicly debated, with scientists like Lord Kelvin and Sir George Stokes taking a prominent public role. The most dramatic scenes in this novel take place in the East End of London along the Thames, where an old man is being rowed by his young daughter in a small boat among the barges and sailing ships. She is horrified as he collects floating bodies for the sake of the few coins in their pockets. The description of the watery environment, on which their livelihoods depend, is focussed on the ripples, waves and eddies produced by boats and tidal currents. A then current apocalyptic explanation is given for the darkening, polluted, atmosphere – namely, the fading strength of the Sun.

> while the Sun itself, when it was for a few moments dimly indicated through circling eddies of fog, showed as if it had gone out and were collapsing flat and cold.

Several literary studies (eg Patrick Brantlinger in *A Companion to the Victorian Novel*, Blackwells, 2005) have suggested that this passage refers to the recent scientific studies by Lord Kelvin in 1862, following the earlier eighteenth-century analysis by Laplace in Paris, which concluded that the sun's power would gradually run down. This was an understandable error, for it was not until the mid-twentieth century that it was understood that nuclear fusion would keep the sun going for several billion years more.

Conversational science

Some novelists use conversations as a very effective way of introducing scientific ideas into their novels. In *Our Mutual Friend*, again, the Gaffer's children Lizzie and Charlie sit in their riverside house looking at the burning coal in the grate, waiting for their father to come home.

> 'Then as I sit a-looking at the fire, I seem to see in the burning coal – like where that glow is now – it comes like pictures to me Charlie.'

> 'That's gas, that is,' said the boy, 'coming out of a bit of a forest that's been under the mud that was under the water in the days of Noah's Ark. Look here! When I take the poker – so – and give it a dig . . .'

After being asked to think, earlier, about the mysterious future of the Sun, here the reader is taken on an imaginary journey back through time to some prehistoric era – of which many of Dickens's readers would have heard in the recent public debates about Evolution and the age of the Earth. The drama later moves to the water's edge, where the waiting becomes ominous. The father's boat fails to return. As elsewhere in this novel, the protagonists are carefully observing their surroundings:

> At this time of their watch, the water close to them would be often agitated by some impulsion given it from a distance. Often they believed this beat and plash to be the boat they lay in wait for, running in ashore; and again and again they would have started up, but for the immobility with which the informer, well used to the river, kept quiet in his place.

This is a significant statement in which one could say that art is leading science. A new concept is introduced: that an eddy or a vortex has an impulse, produced by a force, in this case by the movement of a boat. In fluid dynamics and mathematics this is a subtle and complex idea – still being studied today in different situations – because, although a vortex produces motions over a wide area in different directions, there is overall a net forward motion and force. Dickens cannot have got this idea from those scientific papers on the subject that are best known to us. Gustav Kirchhoff, in Germany, wrote the first paper on the concept four years after the novel was published in 1869, so Dickens could not have read Kirchhoff; nor was Kirchhoff influenced by Dickens. Kirchhoff's idea was later elaborated and publicised by Lord Kelvin, to become known as 'the Kelvin impulse'.

One can think of examples where art foretells advances in science and technology, such as the planets of Mars suggested by Swift in *Gulliver's Travels* or Jules Verne's travels by rocket in space and under water, by submarine. But I don't think Dickens actually foretold this advance in fluid dynamics. If not, then where the Dickens did he get such a technical idea? Probably, in my view, from John Scott Russell, a railway and ship engineer who worked as the railways editor for Dickens in the Fleet Street office of his newspaper, *Daily News*. Russell was the man who first identified how waves had a force associated with them. He explored this idea in his famous experiment – reported to the British Association in 1845 – when he galloped at about 15mph along the towpath of a canal near Edinburgh, to measure the solitary wave or little mountain of water that moves under its own dynamics for a few miles along the canal when a barge suddenly starts to move. He then applied this observation to the design of steel ships – he was involved, with Brunel, in the construction of the Great Eastern – by attempting to minimise the force on the hull that is generated by the waves as the ship moves through the water. It seems quite likely that Dickens would have heard of all this from Russell and made the imaginative leap, but of this I have no proof. I cannot find any correspondence between Dickens and Russell on this topic – but nor does G. Emmerson, in his biography of Russell (1977), make any reference to conversations the two may have had in their newspaper office.

Returning again to the expectant party on the river, as they counted the hours, they made a further interesting observation.

> The wind carried away the striking of the great multitude of city church clocks, for those lay to leeward of them; but there were bells to windward that told them of its being One – Two – Three.'

The fact that sound is apparently only carried downwind had been established experimentally in the 1850's; this is (still) surprising because the speed of sound, measured by Isaac Newton among many others, is much faster than wind speed near the ground. But in the 1850's John Tyndall and Sir George Stokes had explained how, because wind speed increases with height above the ground, the wind bends sound waves upwards from downwind sources of noise, so that they cannot be heard on the ground in the upwind direction. Dickens's text perhaps implies that this is another new discovery, and in yet another new field of science, in this case acoustics.

Science and society

Dickens expressed his general ideas about how new fields of science emerge in his essay on 'History of a young ology' – in *All the Year Round* vol 6 (1861), p187 – his own term for the new sciences of geology, archaeology, meteorology, oceanography etc. He noted that in the early years of an 'ology' there may be a 'vast multitude of results' that might not be 'very accurate or very interesting'. He also recognised that individuals are important, especially at this stage, as in his attribution of progress in the new science of meteorology to Dr Dalton of Manchester. The leaders of science today might agree with this observation, even if they still cannot agree on how best to encourage new ologies. They would probably also agree with Dickens's – and later Poincaré's – views about the value both of explaining science to the wider public and of making connections between the different branches of science.

Dickens's thoughtful writing about science and its contributions to his novels are consistent with his affirmation in the last decade of his life about the broadly beneficial effects of science and technology on the nation and on people's lives. Peter Ackroyd's biography explains that, despite Dickens's reservations about the nationalistic tenor of the Great Exhibition of 1851, 'at the very end of his life he was praising the major discoveries and inventions of his period' that romantic idealists like Ruskin and Morris disparaged. I would agree with Ackroyd's conclusion that 'In that sense Dickens was very much a modern man, very much a man of his period, and highly sceptical about "the good old days"'. Scientists can certainly learn something, even today, from Dickens's ideas and how to convey them in brilliant writing.

Julian Hunt (1960), Lord Hunt of Chesterton and one of 'Tony's cronies' (See The Fountain *8, Spring 2009), is currently researching into the effects of climate change* *on the world's tropical coastlines. This article is based on a talk given at University College London in March 2012 and has benefited from advice given by Giles Foden and Adrian Poole (1967).*

Engineering Repair of the Gates of Great Gate by Chris Morley (1968)

The problem

In 2008 the College Buildings Committee became acutely aware of problems with the magnificent timber doors to the Great Gate. In particular, the North leaf, which is opened more often, had over the centuries become much distorted, so that the moving edge had dropped markedly (about 50 mm) relative to the hinged edge. To prevent the moving edge from scraping across the flagstones, this leaf had several times been lifted bodily by inserting shim washers at its hinges – but this remedy had reached its limit, as the curved top of the woodwork was beginning to foul the curved stonework above the hinges. The South leaf was similarly but not so severely distorted (see Figure 1, which shows the inside, structural, face of the gate), but the North leaf was again scraping on the ground, and becoming very difficult to open. A secondary problem was that the North leaf had bowed significantly out of plane, especially near the top, into a shape incompatible with the alignment of the pins at its three supporting hinges, where several failures had occurred.

What was to be done? In the early stages there were various suggestions. Perhaps the moving edges of the gates could be supported on wheels running on curved metal tracks set into the flagstones below, to prevent further distortion of the woodwork – but this would require carefully-constructed tracks, disfiguring the entrance hall. Perhaps, after the droop had been somewhat reduced by tightening temporary diagonal tie rods across each face (balanced to prevent bowing out of plane), a permanent flat steel frame with prominent diagonals could be bolted to the inside face to prevent further distortion – but this would completely alter the view shown in Fig.1. Perhaps diagonal bracing acting in compression could be provided by carefully fitting wooden diagonal members