Fiction MEETS Science WORKING PAPERS

What Did Scientists Do All Day?

Scientists at Work in British Fiction from the 17th to the Mid-20th Century

Fiction Meets Science Working Paper 1

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1. Introduction

Fiction: Neglected Potential for Science Communication

Academic analysis of communication about the closed and specialized world of science to the wider public has focused on the coverage of science in factual media. But most people read fiction and watch drama as well, and these media also contribute to how people understand the world. Public perception of science is influenced by fictional as well as factual sources (Brake and Hook, 2008; Gordon, 2009; Turney, 2008) and it therefore makes sense to consider fiction as a potentially significant element in the communication of science.

There is a well-established body of scholarship dealing with literature and science, but its focus has been philosophical and literary. Analysis has focused on issues such as the language used by scientists in professional communication, how scientific ideas are used as metaphors in fiction and drama, how scientific theories influence fictional plots and the behaviour of fictional characters, and how developments in science have moved in parallel with the development of the form of the modern novel (see, for instance, Beer, 2000; Dale, 1989; Levine, 1988; Montgomery, 1996; Shuttleworth, 1986: Sleigh, 2011). A subsection of scholarship has looked in detail at 'science fiction' (for instance Broderick, 1995; James, 1994; Lambourne, Shallis and Shortland, 1990; Luckhurst, 2005; Willis, 2006), and educationists have investigated how this genre might be used in the classroom to draw reluctant students into learning science (for instance, Krauss, 1997; Stocker, 1998; Dubeck, Moshier and Boss, 1994). And there has also been some analysis of drama for its coverage of science (Shepherd-Barr, 2006). It is only in the latter contexts of science fiction and drama that fictional texts have been analysed for what they say explicitly about science.

Before considering the full range of fiction for what it might say about science, it is useful to unpick the various meanings encompassed by the single word 'science'. It includes at least three separate, though inter-related, attributes:

1. The behaviour of scientists and the methods employed in research, in what might be called the business of doing science.
2. The results of this activity; the apparently reliable knowledge that scientists generate about the world.
3. The impact of this new knowledge, (and the methods and attitudes that generated it) as it produces technical and cultural consequences for society as a whole.

Scientists themselves generally think that the second attribute, reliable knowledge, is what people want and need to know and reports of such new knowledge dominate factual reportage about science. But humanities and communication scholars have long argued that the public should have a better understanding of the first phase of science, how scientists produce knowledge, which might allow them to better evaluate what science is being done on their behalf (see, for instance, Collins and Pinch, 1994; Irwin, 1995).

This is difficult because the business of doing science is complicated. At the beginning are the political and psychological questions about who scientists are, why they are doing science, and at whose behest they are doing it? Once they start work, scientists' investigations fall into two stages: an initial establishment of matters of empirical fact, followed by the interpretation of those facts. Scientists spend an enormous amount of effort establishing facts and often claim this is their greatest strength, though in practice, the facts have little value without interpretation or the theories and laws that are devised to explain them. It is therefore important to have some understanding of how scientists establish facts and devise explanations, and to address the question of whether the methods are as objective, and the explanations as truthful, as scientists often claim. They may not be. Science is a social process, and the business of gathering facts and devising explanations requires the coordinated work of many people and groups.

These groups include research teams, university departments, learned societies, grant awarding organizations, professional bodies, editorial boards of journals, textbook and monograph publishers, cohorts of people training under the same leaders, and so on. Social interactions among individuals and groups are just as significant for achievement as individual scientist attributes of motivation, competence, imagination, and intellectual rigor. The ideal democratic citizen might have some grasp of all these elements of method; in other words some informal understanding of the philosophy, history, sociology, psychology, and politics of science. But, in practice, the citizen seldom reads or hears much about any of this. These matters tend to be neglected in both the fictional and factual treatment of science (see, for instance, Russell, 2010; Ziman, 2002).

The third attribute of science, its applications and implications, is better represented in both factual media and fiction. The most obvious application of scientific knowledge is in technological innovation, which can lead to useful products and services or to potentially detrimental outcomes. We must be careful not to assume that technological innovation is just the application of new science; in practice, the relationship between new science and new technology is complicated, although media representation seldom

acknowledges this (see, for instance, Basalla, 1988; Mowery and Rosenberg, 1998). Some fiction does deal with these technological issues, but probably more significant are the cultural implications of science, where fiction has often reflected both the unease that can accompany advances in science and celebration of the benefits that may result from those advances (Sleigh, 2011; Ingersoll, 1992).

Writers in the British tradition of Scientific Romance in the late nineteenth and early twentieth centuries were among the first to deal with these issues pertaining to the third attribute of science. A minority of these authors thought the future would be a better place through a combination of technological progress and reorganization of society on scientific principles, and they wrote of utopian societies that were run on rational grounds, based on empirical evidence. But the majority of Scientific Romance writers were pessimists who thought the application of science likely to lead to dystopia. The more sophisticated writers in both camps realised that human beings would not survive in many imagined futures (good or bad), so the species would have to be re-engineered. Typically, this might involve either the removal of emotion, so that humans could operate by reason alone, or the development of some form of communal, telepathic mind that would make them collectively more intelligent (see, for instance, Stableford, 1985; Seed, 1995).

Descriptions of the second attribute of science, its outcomes in factual knowledge and abstract ideas, were, historically, insignificant in British fiction, though it was often suffused with and influenced by scientific ideas—especially ones that had already been incorporated into general culture.

Surprisingly, discussion of the first attribute of science, the business of doing science, is also missing from both factual and fictional treatments of science. Understanding this attribute is important for citizens trying to judge if, when, and why the truths revealed by science transcend those revealed by other means and whether its practitioners are to be trusted, and fiction seems almost specifically designed to deal with it. Fiction can examine personality, motivation, and behaviour—the messy issues of how and why people think and act as they do; it can explore the practical and theoretical problems of doing science, how scientists justify their explanations; and it can tease out the social interactions among scientists and within their institutions. Fiction is uniquely placed to allow readers into offices, laboratories, and field stations—as well as bars, cafes, and conference halls—to explore the machinery of generating knowledge that rarely features in the factual coverage of science (for instance, Mawer, 2005; Van der Laan, 2010). It is the best medium for

exploring the business of doing science because it can deal with good, beauty, and truth, as well as with evil, ugliness, and falsehood.

And yet, in practice, judging from the coverage of science in the specific case of the history of British fiction, it has not fulfilled this potential. Scientists as characters have often been featured in fiction, but not necessarily in the context of their professional work. Roslynn Haynes, in a comprehensive review of the history of scientist characters in global fiction, found they had generally received a bad press, with the exception of engineers in early twentieth-century American novels. Otherwise fictional scientists (or proto-scientists) tended to be either mad or bad; at the worst selfish, evil, or power-hungry and at the best naïve, self-absorbed, and isolated from their families and society. Even when naïve scientists were benevolent, they did not foresee how others, whose intentions were bad, could manipulate their work. Haynes attributes these unfavourable portraits to the persistent influence of a number of literary myths about the dangers of discovering forbidden knowledge. These arose from a distaste for alchemy in Christian Europe because of its Moslem origins, the ill-fated plight of Faust when permitted access to whatever knowledge he wanted, the Christian Fall where Adam and Eve were expelled from Eden for tasting the fruit from the Tree of Knowledge, and Classical pagan tales such as the release of demons from Pandora's Box (Haynes, 1994; Turney, 1998). The same generally unpleasant picture seems to apply to the portrayal of many scientists on film (Frayling, 2005).

I have looked in some detail at a sample of the fictional treatment of science over time in British fiction, written between the seventeenth and the mid-twentieth centuries, to see how the actual practice of science has been treated. This particular sample was chosen because the precursor to modern science, experimental natural philosophy in the seventeenth century, was first described in Britain. As this new approach struggled to gain cultural acceptance in the seventeenth and eighteenth centuries, the problems and virtues of undertaking experimental philosophy were rehearsed in fictional form—in utopias by supporters, and in satires by opponents. After that, a relatively small number of nineteenth- and early twentieth- century novels covered the social context of science, incorporating limited discussion of scientific purpose and procedure. The business of doing science also appears as a sub-plot in some British Scientific Romances written from the late nineteenth to the mid-twentieth centuries. Finally, between the 1930s and the 1960s, a small group of British writers of popular literary fiction addressed the issue directly. But overall, over this long period of British fiction, there was little treatment of the professional lives and work of scientists.

This absence has long been noticed, and possible explanations have been proposed. A practical factor may be the inaccessibility of science to literary readers and writers educated only in the humanities. Another issue may be that the lives and achievements of scientists were of no interest to that critical group of readers (Millhuauser, 1973).

There are signs that this neglected aspect of science is now being explored in fiction. After a fallow period during the 1970s and 80s, the number of novels and plays that address scientific themes has increased dramatically since the 1990s. Many of the writers in this new wave have direct experience of science and find it interesting, as apparently do some readers. One such American scientist-turned-author, Carl Djerassi, claims that he set out specifically to write fiction and drama about the business of doing science (Djerassi, 1998, 2002, 2003). Analysis of this largely twenty-first century phenomenon is just beginning, notably in the 'Fiction Meets Science' project. What follows is a background review of how a small number of British fiction writers dealt with the business of doing science before this recent upsurge of fiction about science began.

2. Utopias and Satires
Experimental Philosophy in the Seventeenth and Eighteenth Centuries: Fiction with a Focus on Process and Procedure

Francis Bacon and the origins of the inductive experimental method

The seventeenth century courtier and philosopher Sir Francis Bacon (1561-1626) undertook a life-long project to improve knowledge about the natural world, in which he formalized a set of methods that were forerunners to modern science. In 1623 he publicized his new ideas by writing a fictional utopia, *New Atlantis* (published in 1627), describing a society in which his plans for 'experimental philosophy' were realised. Prior to this, the most influential such text in England had been Sir Thomas More's *Utopia* (1516). *New Atlantis,* however, was more closely modelled on Continental models, namely Tommaso Campanella's *City of the Sun* (written 1602, published 1623), and Johann Valentin Andreae's *Christianopolis* (1619). Both of these authors saw education in all branches of knowledge as the best way to improve economic performance and social organisation.

On Bacon's island of *New Atlantis,* the most powerful institution is Salomon's House, dedicated to the study of God's works. It has extensive laboratories for experimental investigations and considerable progress has been made. Advances have come from practical observation and experiment; the Fathers

of the House are intellectuals prepared to get their hands dirty. The institution is bureaucratic with a specialised workforce of investigators, supported by armies of apprentices and attendants.

While *New Atlantis* revealed the epic scale of Bacon's vision, there was nothing about how the Fathers actually undertook their work. Bacon described this in the non-fictional *Novum Organum*. Knowledge of natural phenomena could best be discovered by examination (observation) and manipulation (experiment). These were revolutionary ideas for intellectuals: traditionally, nature had been studied by speculative natural philosophy, starting from the written authority of classical philosophers. Since the ancient sources were contradictory, natural philosophers had to develop methods to resolve the differences.

This speculative natural philosophy had strengths, especially deductive logic. Working from a minimum of factual statements, natural philosophers built up explanations by chains of deductive argument, which ensured that conclusions drawn from initial premises were true. But contradictory starting-points from different ancient authorities inevitably led to contradictory conclusions. Bacon aimed to overcome this problem by ensuring that initial starting points were agreed upon based on observation and experiment. But the use of his techniques was open to objection because investigators had to generalise from limited observation, such that the conclusions drawn ultimately depended on inductive reasoning, which could produce uncertainties. Bacon thought that conducting a massive number of observations and experiments would overcome the problem. Working out explanatory laws, hypotheses, or theories was achieved by gradual cross-referencing of low-order data to build general explanations. He tried to overcome inductive uncertainty by sheer weight of data. Bureaucratic methods demanded bureaucratic investigation; the professional courtier based Salomon's House on the model of an efficient civil service.

The majority of natural philosophers rejected Bacon's ideas in his lifetime, but by the 1630s and 40s they were proving influential among a group of English intellectuals. The English Civil War interrupted matters, but when Charles the Second was restored to the English throne in 1660, he agreed to be patron to a group of Baconian experimental philosophers in the Royal Society.

While Bacon expounded the principles of experimental philosophy, it was Copernicus, Brahe, Kepler, and Galileo who made the earliest progress in the major natural philosophical discipline of astronomy, arguing that the Sun, not the Earth, was at the centre of the universe. Just as Bacon had used fiction to publicise his methods, Kepler presented his conclusions about the Solar

System in a fantasy voyage to the Moon in *Somnium* of 1609. Several authors in England also wrote fantasies that incorporated observations about the Moon, including Bishop Francis Godwin, who wrote *The Man in the Moone: or a Discourse of a Voyage Thither by Domingo Gonsales* (1638), and John Wilkins, who wrote *Discovery of a World in the Moone* (1638). Once interesting observational results were available, describing them in fantasies made a better case for experimental philosophy than discourse on its methods could make. From the beginning, fantasies about new knowledge and its implications—the second and third attributes of science—have proved more alluring than fantasies about methods of investigation, the first attribute (Bacon, 1627; Brace, 1999; Brake and Hook, 2008; Chalmers, 1978; Henry, 2002; More, 1551).

The Duchess of Newcastle: conservative backlash

There was considerable opposition to Bacon's ideas from natural philosophers, which persisted well into the era of the Royal Society. One eccentric opponent was Margaret Lucas (1623-1673), a daughter of the Earl of Colchester, forced into exile in France during Cromwell's interregnum, where she married William Cavendish, Marquis of Newcastle. Margaret attended salons in Paris and Antwerp in the 1650s, undergoing a crash course in deductive natural philosophy. One of the main topics was 'atomism'; the theory that nature could be explained by the actions of atoms in motion. There were several versions of this theory and natural philosophers set out to establish from authority and deductive argument which one was right.

Margaret and William returned to England with the restored monarchy and in 1665 Cavendish was made Duke of Newcastle and Margaret became a Duchess. In 1666 she published an attack on the Royal Society as *Observations upon Experimental Philosophy* and published a work of utopian fiction in which she rehearsed her arguments in a fictional context, *The Description of a New World, Called the Blazing World*. Her attack on experimental philosophy exposed weaknesses in its method, which were subsequently explained away, but never completely rebutted. In *Observations* she attacked two main claims made by the Royal Society: the value of experiment and the usefulness of measuring instruments like telescopes, microscopes, and air-pumps. The *Blazing World* is a fantastic voyage, in which the heroine sets out arguments for the superiority of rational speculation and critiques observation and experiment. Observations are dependent on observers, who may be eccentric or incompetent so cannot be relied on, and what they see with their instruments could be artefacts. She also hammers home the point that

observation cannot show immaterial phenomena, such as vacuums or abstract principles.

She plays up the weak point of Bacon's well-known (but downplayed) association with alchemy. Ben Jonson had attacked this practice in his play *The Alchemist*, for which William Cavendish had acted as patron in 1610. Much later Cavendish was patron to Thomas Shadwell (1642-1692) who composed a satirical drama on the Royal Society, *The Virtuoso*, in 1676. This continued the attack on experimental philosophy and was a template for later satires on science (Battagelli, 1998; Cavendish, 1666; Jonson, 1610).

Thomas Shadwell: populist satire on the Royal Society

Shadwell's experimental virtuoso, Sir Nicholas Gimcrack, is a complete fool, undertaking ludicrous researches, conned by suppliers of freak phenomena and unable to perceive domestic plots laid against him. In the end, his world collapses and he regrets studying 'vermin' rather than humans and being concerned with theoretical rather than practical matters.

Shadwell's attack was less sophisticated than Margaret Cavendish. The Royal Society had claimed that experimental investigations would bring practical advantages—that nature could be better manipulated for social benefit and commercial profit. But experimental philosophers seemed interested only in understanding nature, not in applying that understanding to useful ends. The Royal Society turned away from what Bacon had called the 'fruit' of science—its practical application for the betterment of the human condition—and concentrated on the discovery of truth and contemplation of knowledge, what he referred to as the 'light' of science. But to the public practical utility was more important than theory. Abandoning practical application was seen as a betrayal, and the experimentalists were anyway self-deceiving and naïve (Shadwell, 1676; Johns, 2000).

Daniel Defoe and Jonathan Swift: political satirists turn on the Royal Society

While satirizing the Royal Society was amusing, attacking the politically powerful could be dangerous. Politics became volatile in the eighteenth century as a nascent parliamentary democracy emerged with two competing factions, progressive Whigs and conservative Tories. Two of the most influential political commentators were the Protestant businessman, Daniel Defoe (1660-1731), who was initially a Whig, and the Anglican clergyman, Jonathan Swift (1667-1745), who was a Tory.

Defoe's parents were Protestant Dissenters from the Church of England, and in the late 1670s, he attended Charles Morton's Dissenting Academy and was

taught experimental philosophy. Defoe became a businessman and polemicist. In 1705, he wrote *The Consolidator*, a satirical piece that contained a surprising attack on the Royal Society. Defoe's problem was the same as Shadwell's: experimental philosophy's focus on fundamental explanation rather than useful application.

The framework of *The Consolidator* is a series of mythical voyages to the moon where politics and religion are better arranged than on Earth. Getting to and from the moon demands a machine called the *Consolidator*, which is able to fly with terrestrial bird feathers—the best ones for the purpose chosen by the people of Earth. This imaginary mechanical device then transforms into a metaphor for the undemocratic governments of Defoe's time.. Among his satirical targets, Defoe attacks the Royal Society. As a businessman who liked to invest in advanced manufacturing (he put money into improved diving suits and farmed civet cats for perfume), he was incensed that the Royal Society had abandoned the practical applications of new knowledge.

Defoe's Tory rival, Jonathan Swift, hated experimental philosophy outright. He wrote a critique of the Royal Society in the third part of *Gulliver's Travels* in 1726, the voyage to Laputa, which describes a dystopian society controlled by experimental philosophers. In Laputa, nothing works and all practical matters are in decay because experimental philosophers govern the state and are concerned only with theories of maths and music. Swift had attended meetings of the Royal Society and his descriptions of the experiments of the 'projectors' who work in Laputian academies are distorted versions of real experiments reported in the *Philosophical Transactions of the Royal Society*. All the projects are useless; all the projectors are poverty-stricken and filthy because they are too obsessed to look after themselves. Swift's list of pointless experiments is interminable; the Fellows of the Royal Society are wasting everyone's time with their experimental foolery. (Defoe, 1705; Novak, 2001: Russell, 2010; Swift, 1726; Vickers, 1996).

Eighteenth-century utopias

The popular genre of the 'desert island' story explicitly stressed the primacy of practical expertise over theoretical explanation, the fruit of experimental philosophy over its light. These fictional islands were often utopias, or sometimes Arcadias (places with such abundant resources there is no need for political economy to share them out). In other cases, conditions were harsh and the problem was surviving at all.

The most famous desert island story was Defoe's *Robinson Crusoe*, written after he had withdrawn from political propaganda. The book drew much of its veracity from the real adventures of Alexander Selkirk, who had spent four

years marooned on an island off Peru. Defoe also made his story vivid by drawing on accounts of real islands, trades, and manufactures, and from his own experience in business. Defoe's story is 'Baconian'. Crusoe on his island is concerned with practical matters so his experiments are all of the fruit type. The island is no paradise, and Crusoe needs useful knowledge to solve practical problems. Defoe gives readers a positive picture of the skills of artisans; it is their kind of knowledge that enables Crusoe to survive, which serves as covert publicity for an applied Baconian approach to knowledge, although Crusoe himself does not conduct any specifically scientific experiments.

A more thoroughly experimental account of desert island life is Robert Poltock (1697-1767), *Life and adventures of Peter Wilkins,* of 1751. Wilkins undergoes the same kinds of experience as Crusoe but is more rigorously experimental. He also encounters a race of flying people and enters a relationship with one of them. Here, the Baconian graft of survival is mixed with escapist sexual fantasy. Wilkins finds it harder to survive than Crusoe, for game and fish are in low supply. He samples unknown fish for palatability and preserves them and other game by boiling and salting. He systematically samples fruit and vegetables, trying them both raw and boiled and finding he can make powders, pastes, treacle, and pulps, and he conducts experiments with gourds to make containers. He devises nets from weeds and catches fish that yield lighting oil. His survival depends more on logically organised experiments than Crusoe's casual observations (Baines, 1995; Carey, 1999; Defoe, 1719; Novak, 2001; Vickers, 1996).

An early 19th century satire: Dickens lampoons the British Association for the Advancement of Science

Another important early scientific institution was the British Association for the Advancement of Science (BAAS), founded in the early nineteenth century to counter the increasing conservatism of the Royal Society. In 1831, a cadre of Fellows led by John Herschel, Charles Babbage, and David Brewster founded the British Association for the Advancement of Science with the aim of making science a professional career. The Association's main activity was bringing together scientists to explain their latest research at annual meetings in different provincial cities. These activities stimulated a heavy-handed satire from the young Charles Dickens (1812-1870) in reports on the 'Mudfog Association for the Advancement of Everything', collected as part of his *Sketches of Young Gentlemen* in 1838.

The Mudfog Association is confused and concerned only with the obscure and the tedious. Rather than presenting a united front, the community splits into

specialist sections and the participants wear themselves out before the meetings arguing over which inn to stay at. This satire attempted to undermine the scientific community's efforts to present science as a united professional practice. In the spirit of Shadwell and Swift, the papers read are nonsensical and the reactions to them farcical. Dickens' critique of science was hardly penetrating, however. Apart from his stab at vivisection, which would prove an on-going sore point for the biomedical research community, it relied mostly on a naïve reading of the eccentricity of scientific work (Dickens, 1838; Golinky, 1992; Hall, 1984; Holmes 2008; Morrell and Thackray, 1982).

3. Victorian and Edwardian Literary Fiction
Science and Social Aspiration

New times, revised methods

The scientists in nineteenth century literary novels were rather different creatures from the experimental philosophers of Defoe's and Swift's satires. The experimental method had been accepted across Europe after the universal embrace of Isaac Newton's theories of physics in the eighteenth century. Newtonian mechanics dominated experimental philosophy until progress in chemistry, electricity, and magnetism revealed phenomena at odds with Newton's vision of a universally harmonious machine (Dodds, 1991; Golinsky, 1992). Romantic Poets were at the forefront in mounting a reaction to Newtonian mechanics, lauding intuition, the unconscious, and the imagination over the accumulation of data, and tedious production of Baconian laws (Wyatt, 1995). And experimental philosophers themselves developed methods that used intuition and imagination. John Herschal set down this fresh approach in his *Preliminary Discourse on the Study of Natural Philosophy* published in 1831.

The revised method had three stages. First observations and experimental data about a phenomenon were carefully gathered, preferably in numerical form. Next a possible hypothesis to explain it would emerge, perhaps by Baconian induction, but more likely by creative imagination. The strength of the revised scientific method lay in its third stage, testing the new hypothesis through further observation and experiment to see whether any predictions deduced from it turned out to be true. If they were confirmed, the hypothesis became a possible explanation for the phenomenon (Holmes, 2008).

With their new methods, nineteenth-century scientists had new aspirations. What in the seventeenth and eighteenth centuries had been a hobby for intellectual gentlemen open to anyone who was interested became a closed

profession and for some a paid career. Making headway in this new science required specific education and training, expensive apparatus and equipment, and dedicated laboratory space. With the arrival of paid posts and government scholarships later in the century, the sort of people who could contemplate a scientific career spread across the social spectrum (Barton, 2003; Cardwell, 1972; Meadows, 2004; Montgomery, 1996).

Scientist characters appeared in a small number of canonical Victorian and Edwardian novels. The experiences of the fictional scientists mirrored the actual transitions experienced by the emerging profession and explored the often-uncomfortable changes to their social status and expectations. Characters struggled with social, cultural, and financial problems in developing their interests and talent. These transitions in science occurred in step with developments in related professions like medicine and engineering, and are also reflected in the lives of doctor and engineer characters in these novels (Russell, 2007).

Elizabeth Gaskell and George Eliot: elements of the professional life

Defoe had been a leading literary Dissenter in the early eighteenth century. A century and a half later, another dissenting Unitarian, Elizabeth Gaskell (1810-1865), became a leading literary figure of the mid-nineteenth century and was the first Victorian literary author to put scientist characters in her novels (Uglow, 1993).

Gaskell's most famous novel, *Wives and Daughters* (1866), is set in the 1820s and 30s with a plot involving two local gentry families, the grand Whig Cumnors and the near bankrupt Tory Hamleys. One son in each family demonstrates a talent for science. A considerable amount of information emerges about the social relationships among scientists at the time, although both of these characters stereotypically lack social skills. Lord Hollingford, the heir to the Cumnor estate, is financially amateur but behaviourally professional, a scientist who can fund his own work. He lacks aristocratic urbanity and wit and has all the tedious features of a pedant. He meets other leading practitioners at national and international conferences and entertains visiting foreign scientific dignitaries at home. He is on the committees of learned societies and in a position to direct the limited funding opportunities available at the time.

The situation for the poverty-stricken Hamleys is very different. The older son, Osborne, must marry money while the younger, Roger, will have to make his own living. Roger is socially awkward while Osborne has all the gentlemanly advantages: good looks, scintillating conversational skills, and academic ability in the classics. But he throws everything away to take up with an

impoverished French girl. In compensation, Roger proves surprisingly successful. He is a gifted naturalist and passes the Cambridge Mathematical Tripos as Senior Wrangler (the top graduate) to be automatically granted a College fellowship, a route taken by many actual scientists in the nineteenth century. Hollingford finds him funds for a global specimen-collecting trip, and this makes his scientific reputation. But he does not have independent means. Gaskell died before the book was completed, so we do not know how she might have portrayed him make a living as a scientist.

Gaskell's two gentleman scientists had the opportunity to make contributions to science, but by the mid-nineteenth century it was difficult for busy professionals to make significant spare-time contributions. Gibson, the local surgeon, is scientifically trained and socializes with Hollingford. While Gibson keeps abreast of developments, as a surgeon he does not have time for research. George Eliot's rural surgeon, Tertius Lydgate in *Middlemarch* (1871) is more active in science, aspiring to make scientific contributions like those of real medical practitioners such as Edward Jenner (smallpox immunization) or Gideon Mantell (dinosaur fossils).

Lydgate's ambitions to be a serious scientific player are limited by the financial strains of early marriage to the socially ambitious Rosamond Vincey and his lack of skills in building a medical practice. As an idealist, Lydgate prefers to treat the underprivileged, a sure way to restrict his income. He wins patients in the early days with advanced, high-profile treatments but then upsets them with requests for post-mortem dissections. Rosamond is unhappy when she learns that he is losing patients through his 'vampire' work. Eliot undertook extensive research to establish the state of medical science in the 1820s and had first-hand experience of establishing a medical practice from the failure of her brother-in-law in managing one such practice. In the post-novel Finale, Eliot has Lydgate die of diphtheria at the age of fifty, after publishing just one learned medical monograph on gout, a disease of wealthy patients (Ashton, 1996; Cadbury, 2001).

Thomas Hardy, Wilkie Collins, George Gissing and H.G. Wells: the business of doing science with difficult social negotiations

Thomas Hardy (1840-1928) drew a comprehensive picture of a scientific character in Swithin St. Cleve in *Two on a Tower* (1882). Swithin dreams of becoming an astronomer and rigs up an observatory in a tower on the local estate. There he catches the eye of Lady Viviette, an older but still attractive woman. Swithin makes a promising start testing a theory about variable stars and is about to submit a paper to a scientific journal when he learns that the real American astronomer, E.C. Pickering, has published the same idea (which

he did in 1881). Swithin is beaten because he does not have a sufficiently powerful telescope but Viviette buys one for him and assists in making observations, allowing Hardy to expound a considerable amount about scientific method, as Swithin explains what he is doing to Viviette.

Swithin's talent is developed with the help of a great uncle who leaves him a legacy to spend on astronomy. He uses the money to join a party going to the Southern Hemisphere to observe a transit of Venus. He has the necessary experience, but is only able to put it to use because he can pay his own way. On his return, Viviette dies, removing financial support for his work, which might be the end of his scientific ambitions.

Wilkie Collins (1824-1889) published *Heart and Science* in 1883, a novel with a strong anti-vivisection subplot. The British anti-vivisection debate of the 1870s and 80s was triggered by audience disgust at the 1874 British Association annual meeting when the French physiologist, Magnon, injected absinthe into a dog's thigh. In 1876, experiments on live animals were permitted by new Home Office regulations, but the issue erupted again in 1881, when the British Medical Association campaigned against the regulations.

Heart and Science was written in 1882 during the second stage of the dispute, and has a labyrinthine plot involving a young surgeon, Ovid Vere, and his mother, Mrs Gallilee. Mother and son are portrayed as opposites. Ovid is a clinician who believes that insights about disease are best obtained with human patients while his mother is a rational devotee of science. Within her scientific circle is the physician, Benjulia, a cold-hearted doctor who has turned to science and has a laboratory where he conducts research on live animals. Like Ovid, Benjulia is studying brain disease, and he fears Ovid will understand a particular neurological disorder before he does. While in Canada, Ovid, who is recovering from a breakdown, comes into possession of a manuscript of clinical research on the disease. When he returns to England he has it published, bolstered by arguments from his own clinical work. He solves the problem before Benjulia, whose intemperate rage leads him to destroy his laboratory and commit suicide. The reader is left in no doubt that Collins disapproved of vivisection, using a pivotal conversation between Benjulia and his brother to rehearse the main arguments on both sides in the debate (Farmer, 1996).

The implications of science in contemporary culture feature in another novel, *Born in Exile* (1892), where George Gissing (1857-1903) rehearses arguments between Christianity and scientific materialism while revealing the intense social dilemma of a lower middle-class aspirant to a scientific career. Gissing's

hero, Godwin Peak, gnaws away at his class limbo. As the book opens he attends a prize- giving ceremony at his college. He has a friend from a similar background, Earwaker, and rivals from gentry backgrounds including Buckland Warricombe, a progressive atheist. The ceremony accentuates Peak's shame at his humble background, which reaches its apogee when he learns that an uncle intends to open a student café. To avoid social disgrace, Peak transfers to the School of Mines in London.

Ten years later, he is working for a chemical firm in Rotherhithe. A gentleman acquaintance who used to work there, Christian Moxey, has funds to do his own research in a domestic laboratory, of which Peak is jealous. He is forced to work in routine chemical analysis while his real interest is in geology, and he accumulates enough savings to take a year off to do some real research. He has kept in touch with the public debate about science and religion and has used his old friend Earwaker, now a radical journalist in London, to help him publish an anonymous diatribe against orthodox Christianity for its refusal to accept the materialistic implications of geology.

Everything in Peak's life changes as chance brings him into contact with his old rival Warricombe's sister, Sidwell, and he spends time on the Warricombe estate. He gets to know their Anglican father who is a gentleman geologist. Peak envies the old man's collections and freedom to pursue geology as he wishes. He and his wife and daughter are religiously conservative, and the old man wants to find arguments in favour of the co-existence of geology and revealed scripture. Peak conceives a mad plan to train as a clergyman so that he can argue for religion, thus winning the love of Sidwell and the respect of her father, and will have enough spare time to devote to geological research. Needless to say, the plan unravels when Buckland exposes Peak as the author of a virulent attack on religion and he is forced to return to chemical analysis.

H.G. Wells (1866-1946) published a number of literary novels between 1900 and 1915, and in several of these, scientists or aspiring scientists, have leading roles; for instance in *Love and Mr Lewisham* (1900), *Tono-Bungay* (1909) and *Ann Veronica* (1909). *Love and Mr Lewisham* focuses on Lewisham's moral weakness in succumbing to sexual desires, which he can only quench by early marriage, but this interferes with his studies as a trainee science teacher on a government grant at the Normal School in South Kensington. He is jealous of fellow students who are comfortably middle class, not struggling on meagre scholarships. His small bursary and his wife's failure to find work and subsequent pregnancy force Lewisham to abandon his studies. A career in science is open to talented lower middle-class boys in the late nineteenth century, but only if they can survive the rigorous path to qualification.

In Wells's satire on the mass marketing of quasi-medical tonics, *Tono-Bungay*, the young George Ponderevo is apprenticed to his pharmacist uncle Teddy. Like the fictional Lewisham and real Wells, George takes classes and exams organised by the government Science and Art Department. Teddy goes bankrupt and is forced to sell up, but George stays on apprenticed to the new owner and takes courses offered by the Pharmaceutical Society. He passes so well that he is offered two scholarships, one for a technology degree at the Consolidated Technical Schools in South Kensington, a gloss on the City and Guilds College located near the Normal School. He takes this up, as he is more interested in engineering than pharmacology.

His uncle Teddy bounces back with a new patent tonic, 'Tono-Bungay', which he sells by mass marketing and display advertising. George takes a role in manufacturing and obtains patents for significant engineering and packaging improvements. With the firm established, George drops out to follow his engineering interests, publishing theoretical papers on the physics of flight and developing prototype gliders, balloons, and heavier-than-air flying machines. George finds himself in the position of a gentleman scientific devotee, but as a lower middle class hero he does useful work in technology rather than pure research on abstract principles.

Ann Veronica Stanley in *Ann Veronica* also starts out on a scientific career at a minor women's college, topped off with a final year at the Central Imperial College. Like Lewisham, she fails to make the grade, in this case doubly disadvantaged as lower middle class and female. She is allowed the escape route of an upwardly mobile marriage to the older zoologist Capes. If she had not escaped, Ann Veronica's fate would probably have been school teaching; even analytical jobs like Peak's were not easy for women to acquire until the 1930s.

Peak, Lewisham, Ponderevo, and Anna Veronica all depend on scholarships for their education. The state set up institutions to offer qualifications in applied science and technology, but the uptake of these courses was disappointing. The key reason was the lack of elementary science education in schools. Reluctantly the government agreed to produce more science teachers by setting up teacher training colleges (Normal Schools) and offering scholarships. Wells was a major beneficiary, attending the new Normal School in South Kensington on a state scholarship from 1884 to 1887. In Gissing's and Wells's experiences, too many aspirants to science found their options restricted to teaching or technical analysis unless they were exceptionally able or lucky. The people who colonized the exciting but small world of pure scientific research were those who could afford to work for nothing or take modest salaries (Argles, 1964; Forgan and Gooday, 1996; Perkin, 1989).

4. British Scientific Romance
The Third Attribute of Science Dominates.

The extent of the genre

Charles Howard Hinton, a British science and maths teacher, published a collection of stories and essays titled *Scientific Romances* in 1886. Hinton's pieces set science in a wide cultural framework, speculating about a fourth dimension, discussing philosophical elements of science, such as causation and perception, and examining the relationship between materialist science and spirituality.

The term 'scientific romance' was then applied to a genre of British fantasy that focused on speculation about the third attribute of science, its future technical and cultural impacts. A small number of books of this type were written before Hinton coined the term, the pioneering text being Mary Shelley's *Frankenstein: or the New Prometheus* (1818). From 1886 until the outbreak of the First World War, many authors wrote hundreds of romances, the greatest exponent being H.G. Wells with a string of eleven romances (and many more short stories) between 1895 and 1914. Several literary writers also turned to the genre, notably Ford Maddox Ford (in collaboration with Joseph Conrad) in *The Inheritors* (1901), and E.M. Forster with a pivotal short story, 'The Machine Stops' (1909).

The tradition continued, less prolifically, between the two world wars, generating one canonical text, Aldous Huxley's *Brave New World* (1932) and books by two other authors that are still widely read today: Olaf Stapledon's *Last and First Men* (1930) and *Starmaker* (1937), and C.S. Lewis's trilogy, *Out of the Silent Planet* (1938), *Perelandra* (1943) and *That Hideous Strength* (1945). After the Second World War, as American science fiction graduated from juvenile pulp to adult magazines and book-length stories, British scientific romance did not remain an independent genre. But its essence lingered on in George Orwell's *1984* (1949) and in the work of John Wyndham, who consciously set out to write stories in the style of H.G. Wells and gained mainstream literary approval with several titles, starting with *The Day of the Triffids* in 1951. Scholars disagree about the historical, literary, and cultural relationships between British, American, and European speculative fantasy fiction and whether British scientific romance should really be considered a separate category. But here it makes sense to consider it as an independent phenomenon (Stableford, 1985; James, 1994; Broderick, 1995; Seed, 1997; Luckhurst, 2005; Willis, 2006).

There were three major themes in scientific romance. The most pervasive was the relationship between science and faith, and many of the writers concerned were sons of clergymen, unable to square their interest in science with their religious backgrounds. The second core concern was the implication of the theory of evolution for the future of the human race, and the third was speculation about political and social organization in a future dominated by science and technology. Scientific romance also dealt with public expectation of higher living standards from better technology, although excitement about such possibilities was tempered with pessimism that technology would be misdirected with dire consequences. The majority of scientific romance writers took the pessimistic view that things would go wrong, their scientist characters being evil rather than virtuous, stereotypically bad or mad, detached and inhuman, lusting for power or wealth, descendants of mythological alchemists and magicians (Stableford, 1985; Haynes, 1994). Such fantasy scientists owed more to literary history than contemporary science. Furthermore, romance writers were not concerned much with the business of doing science. For these reasons, scientific romances, with a few exceptions, are generally poor sources of knowledge about scientific process and procedure.

Proto-Scientific Romance: The Genre Before Hinton

The first proto-scientific romance was Mary Shelley's *Frankenstein* (1818). Shelley set out to explore the nature of life and mind, both of which entailed conflicting spiritual and materialistic interpretations in the nineteenth century. On the spiritual side, life was caused by a God-given vital force, with mind the product of an immortal soul divinely placed in the material body. On the materialist side, life was an innate property of the organization of animals and plants, with mind arising from the innate functions of nervous tissue in the brain. Shelley's scientific protagonist, Victor Frankenstein, is a materialist who creates a living being to show that vital forces are not needed. After much labour on materials taken from graveyards, dissections, and slaughterhouses, he creates a huge living creature. The details of the experimental work are vague, though the implied animation force is electricity. Victor finds his creation vile, and the creature escapes, learning much about human nature but terrifying all who encounter him. Starting with good intentions, the creature's experiences make him evil. Shelley did not intend Frankenstein to be a simple scientific over-reacher who was punished for his presumption. His literary role was more sophisticated: to stand for the mixed implications of scientific materialism (St Clair, 2000; Turney, 1998).

Edward Bulwer Lytton (1803-1873, Lord Lytton from 1866) was an immensely popular novelist fascinated by science and the occult. *Vril: The Power of the Coming Race* (1871) is set in the present below the Earth's surface. The *Vril-ya* are subterranean descendants of a human race that once lived on the surface, and they will eventually return and exterminate the peoples living there. They are 'the coming race,' and the book serves as a warning to mankind. Their advanced science discovered 'vril', a sort of electro-magnetism universally present in the world, resembling the animal magnetism of contemporary nineteenth-century mesmerism and hypnosis. The shapes of *Vril-ya* skulls, as judged by the contemporary science of phrenology, show their brain areas for benevolence are large, while those for combat are undeveloped. *The Coming Race* is unusual among proto-romances in imagining a society based on science, and Lytton gives some account of *Vril-ya* scientific institutions. The purpose of their scientific research is Baconian: The conditions of life should be better understood for everyone's benefit, and the researchers work for pleasure, not fame or wealth. The work is done in Colleges of Sages, where many of the professors are young, unmarried women who have the time to do culturally enriching but (in the first instance) useless research, for which considerable public reputations are made. In this society, useless science coexists with the useful, and the useless is both necessary and praiseworthy (Brown, 2004; Bulwer Lytton, 1871).

In the actual scientific world of the second half of the nineteenth century, the German mathematician Bernhard Riemann developed a geometry of four dimensions by logically extending the maths of three-dimensions. He imagined that the physical forces experienced in our three-dimensional world were produced from a crumpling of that world through an unseen fourth dimension. Such ideas led eventually to Einstein's theories of relativity and cosmology, and they also fascinated fantasy writers. The Reverend Dr Edwin Abbott published *Flatland, a Romance in Many Dimensions* (1884) to develop Riemann's speculations. Abbott was a teacher who retired early to write on a wide range of educational, philosophical, and theological matters. In *Flatland* everything exists in two-dimensions, and it is hard for two-dimensional beings to conceive of a three-dimensional cube. *Flatland* grapples (obliquely) with the tensions between scientific materialism and spiritual Christianity. Abbot wrote extensively about science and faith, arguing that they were not only compatible but also essential for each other. The drift towards materialistic science to the exclusion of the spiritual—exemplified earlier in *Frankenstein* and *Coming Race*—was being reconsidered in the late nineteenth century from both the scientific and theological sides. Abbott and, a little later, Hinton, were both critical of what they saw as pernicious twin

influences on the public understanding of scientific method: fundamentalist Christianity, which could not accept that religious texts were metaphorical, and the popularity of naïve Baconism. People were still suspicious of the concept of hypothesis and the role of imagination in science. Abbott wrote *Flatland* partly as an allegory of such misconceptions: the problems the two-dimensionists face are a critique of the failure of both science and religion to understand the significance of human imagination (Abbott, 1884; Farnell, 2005; Jann, 1985).

The Heyday of the Scientific Romance, 1886-1914

Two near-canonical novels in the scientific romance tradition appeared before 1900: Robert Louis Stevenson's *The Strange Case of Dr Jekyll and Mr Hyde* (1886) and Bram Stoker's *Dracula* (1897). Both deal extensively with the scientific process. In *Jekyll and Hyde*, Stevenson combines realistic laboratory shop-work in which increasingly pure chemical reagents are used, with fantasy science. While Stevenson's science is purely materialistic, the later *Dracula* reflects the revival of the idea of spirituality alongside materialism and even implies that spiritual phenomena might have materialistic explanations.

In *Jekyll and Hyde*, Henry Jekyll is a medical practitioner with a taste for scientific research, intuitively aware of a duality in his nature: a higher spiritual, reasoning, and moral element, which are truly 'human', and a lower, animal-like component, which he associates with evil. He discovers how to separate himself into two people with these two opposing moral tendencies. The higher character remains Henry Jekyll, while the lower is the brutish Edward Hyde. Jekyll's fantasy experiments are based in two areas of real science: neuro-anatomy, which showed human emotional and reasoning capacities to be in separate hemispheres of the brain, and Darwin's theory of evolution, which showed that humans had evolved from animals. To the Victorian mind, all animals were devoid of human reason while humans had only a thin veneer of rationality over a deep core of animal character. Jekyll's experiments revealed the evil animal characteristics inherent in humans from their evolutionary past.

Jekyll uses sophisticated chemistry to convert himself back and forth between Jekyll and Hyde but falls foul of a practical problem with chemical reagents. His stock of an essential chemical runs out. He obtains replacement batches, but they fail to react like the first one. He first guesses the new supplies contain a contaminant that interferes with his chemical reactions. But the preparation of pure chemical reagents had been improving, so he suspects the problem lies with his original batch, probably contaminated with an unknown component essential for his transforming chemistry. He gets suppliers to

trawl back through older batches to check for the same contaminant, but in vain. Facing the prospect of remaining permanently as Hyde, Jekyll prefers to kill himself (McNally and Florescu, 2001; Stiles, 2006).

Bram Stoker's (1847-1914) composition notes for *Dracula* contain many entries on hypnotism and brain injury and he owned a number of textbooks on physiology, brain science, and criminology. But his story integrates materialism and spirituality, reflecting the contemporary rear-guard reaction against materialism, especially in the physical sciences, psychology, and the study of insanity. The five hundred year old Transylvanian vampire, Count Dracula, comes to England and settles in a decaying estate outside London and is able to use his devilish powers to control nature. Ranged against him is a crew of light, including the young lawyer, Jonathan Harker, and his fiancé, schoolteacher Mina Murray, both enthusiastic rationalists, masters of the complexities of Victorian train timetables, and in Mina's case the new arts of taking shorthand and typewriting. Their leader is the Dutch scientist and expert on vampire culture, Dr Van Helsing of Amsterdam, assisted by his ex-student, John Steward, superintendent of a private lunatic asylum next to Dracula's estate. Mina's best friend, Lucy Westenra, is a dreamer who proves so susceptible to Dracula that she becomes a vampire herself.

Van Helsing uses a range of traditional tools against vampires, but it is scientific method that enables the crew to destroy him and partly explain his supernatural powers. Two of the new 'sciences' exploited by the crew are hypnotism and telepathy, which together explain Dracula's paranormal powers and allow Van Helsing, through Mina, to track Dracula when he is far away. The emerging understanding of mental illness suggests how the insane Renfield could also become a target for the vampire. Blood transfusion, to compensate for blood loss from vampire feeding, and the technology of sound recording, for Seward's labour-saving audio diary, provide visions of the near future where these two emerging technologies might find cultural use (Reed, 1997; Forest, 1999; Luckhurst, 2002; Morton, 2004; Nichols and Bowie, 2001; Porter, 2002; Senf, 2002; Stiles, 2006; Frayling, nd).

The crew of light operates like a research team in its meticulous collection and recording of data, and its cross-correlation of records from different places and times. Van Helsing, in hypothetico-deductive mode, theorizes the Count's behaviour in the light of accumulated history and current vampire lore, and then tests the validity of his hypotheses by predicting where the Count will be and what he will do.

As a spiritual being, Dracula has access to cosmic telepathic networks which allow him to control natural phenomena and communicate with his victims

from a distance, if they are in pseudo-trance states like dreaming, sleep-walking, or hallucination. At the time, telepathy was considered naturalistic, so the supernatural communication mechanisms and mind take-overs of fictional vampires were explicable in materialistic terms. Lucy Westenra submitted to Dracula because she was suggestible; Dracula spoke to the insane Renfield through his hallucinations. Van Helsing's scheme for tracking the Count with telepathy is close to full naturalism. Mina Murray is forced into a symbiotic relationship with Dracula through exchange of blood, and this connection establishes a telepathic communication between them. As a being already on a deep spiritual plane, Dracula has direct telepathic communication with Mina's mind, but for her to initiate contact with the Count, Van Helsing has to put her into a trance. As a mere human, even in a trance, Mina has only vague sensory impressions from Dracula, but this is enough for Van Helsing to make intelligent guesses (formulate scientific hypotheses) about what the Count is doing. The crew of light triumphs against Dracula's evil power by maintaining a scientific attitude and applying scientific methods.

Most other scientific romances explored the cultural consequences of scientific ideas with little scientific knowledge expounded and even less concern with scientific process. One minor exception is Conan Doyle's *The Lost World*, in which Professor Challenger argues about a contemporary scientific idea, Weissman's theory of inheritance. This theory undermined the pangenesis espoused by Darwin, worrying Challenger—as it did many actual Darwinists—because it shed doubt on the theory of natural selection. Conan Doyle liaised closely with a leading palaeontologist, Ray Lankester, over the details about dinosaurs, and Lankester approved the story, even though it had a world where ancient creatures co-existed with species that had not yet evolved. Lankester thought the errors worthwhile in return for popularizing Darwinian evolution (Stashower, 1999).

Challenger does not see why his word alone should not be accepted, he does not bother to rationally discuss evidence. In *The Lost World*, Challenger and his colleague Summerlee never agree on anything unless a third-party scientist is mentioned, at which point they both attack the latter's opinions. Conan Doyle pokes fun at the public image of science as a unified front, supposedly the result of refined behaviour by its practitioners. Instead he suggests scientists are as selfish, amoral, and argumentative as anyone else.

The most prolific exponent of scientific romance, and the writer who had the most to say about all three of the attributes of science, was H.G. Wells. Wells was a self-taught student of Whig literature who had trained as a teacher on a government scholarship, obtained a first class degree in zoology, and

occasionally worked as a schoolmaster and journalist. In the almost twenty years between the publication of his first romance, *The Time Machine,* in 1895 and the First World War, Wells became a major literary figure with a prolific output of short stories, romances, and serious novels. He believed a form of socialism could liberate working people from exploitation by industrial and mercantile power, but he was also psychologically rebellious and fell out with the intellectuals who led Britain's main socialist group, the Fabian Society, whose leaders also despised Wells as a jumped-up cockney.

Wells rejected Fabian gradualism. He believed in achieving social justice through autocratic government by enlightened intellectuals (Platonic Guardians) who would organise society for everyone's benefit. He saw science and technology as potential solutions to social and political problems and thought scientists could be versions of the intellectual giants who should be responsible for government, although this position appalled his Fabian colleagues. Wells favoured war as a social cleansing agent, until his experience of actual conflict disabused him of this notion. But he admired the planned societies envisaged by both communists and fascists in the 1920s and 30s. Many of his political and social attitudes were expressed in his romances. While he saw science and technology as routes to social improvement, he nevertheless thought scientists and engineers should be under social control. While he believed that scientists should govern, he knew that in practice many scientists were unsuited for government (Foot, 1985; Haynes, 1980; Parrinder, 1995).

Wells's eleven scientific romances, published between 1895 and 1914, were infused with political and social idealism almost from the start, and this became more marked in the later romances. Wells wrote the stories to explore large-scale themes of the impacts of science and technology, the third attribute of science. The stories are made plausible by Wells's ability to drop in well-understood scientific principles and devise convincing fantasy scenarios based loosely on the application of evolutionary and other scientific ideas (Bergonzi, 1961; Haynes, 1980). In some cases, he presented surprisingly detailed accounts of the business of doing science, although scientific knowledge and scientific process are peripheral to his central purpose of exploring the future socio-political changes that science might bring about.

Scientists undertaking fictional research appear in *The Time Machine* (1895), *The Island of Dr Moreau* (1896), *The Invisible Man* (1897), *The First Men on the Moon* (1901), *The Food of the Gods* (1904), and *The World Set Free* (1914). The first three, the time traveller, Moreau, and Griffin, the invisible man, are often interpreted as alchemists. But the time traveller is a respectable physicist, author of seventeen papers published in the *Philosophical*

Transactions of the Royal Society. Though he builds his machine in secret, his scientific credentials and motivation—curiosity rather than wealth or power—counter the alchemical archetype.

Moreau is also motivated by curiosity to see if he can make humans from animals. He does not seek wealth or political power. He was forced to leave London after his vivisection practices were exposed. His excesses revolt Prendrick, the naturalist narrator of the story, but Prendrick does not approve of popular opposition to vivisection. Moreau was doing valuable research in London, his methods justified by the knowledge obtained, and Prendrick castigates the research community for not coming to Moreau's aid. While Wilkie Collins's anti-vivisection position was obvious in *Heart and Science*, Wells's opinion on the issue is not clear from his text.

Griffin's motivation in *The Invisible Man* is also curiosity rather than lust for wealth or power. He wants to discover a science of invisibility, using himself as an experimental subject. He too works in secret, but justifies this because he does not want to share credit with a boss he hates—an unethical stance, but not unknown in scientific circles. Because desperation to some extent drives his vile behaviour, calling him an alchemist misrepresents him. Cavor, the scientist in *First Men in the Moon* also wants to satisfy his curiosity to the exclusion of all else, a behaviour that was satirised from the earliest days of the Royal Society. Cavor's curiosity about the Selenites (moon dwellers) is so strong that he welcomes being captured, because he will learn more about them.

Wells also introduces entrepreneurs and engineers, who are very different from scientists. Bensington, a chemist, and Redwood, a physiologist, are satirised in *Food of the Gods* as shabby, eccentric, narrow-minded, and so focused on science that they cannot produce the technical innovations they envisage. They need business input, and this is provided by the entrepreneurial doctor, Winkles, who is initially engaged so that 'Boomfood' can be medically prescribed. Winkles, however, is eager to exploit its money-making potential. The scientific duo is more cautious, but Winkles takes it upon himself to be the public relations expert for Boomfood. He is also a prominent member of a Royal Commission that finds the dangers of Boomfood greatly exaggerated, just as another nasty outbreak of giant vermin is reported. The scientists retain their innocence, and while business is necessary for innovation, those with business interests are often unscrupulous.

Cavor's partner, Bedford, in *First Men on the Moon* is another businessman. Bedford cannot understand why Cavor wants to go to the moon, since he can imagine more profitable ways of using anti-gravity on Earth. It is only the

possibility of finding minerals on the moon and of developing space tourism that persuades him to participate.

Technical innovation also needs engineers and Wells introduces Cossar in *Food of the Gods* as a man of action. His clean-up of the farm where the experiments with Boomfood have gone wrong is so efficient that Bensington is forced to admire him, despite the fact that Bensington is an intellectual while Cossar is a mere applied scientist. Cossar does not share Bensington's doubts about the wisdom of feeding Boomfood to babies and gives it eagerly to his three children, ultimately helping them build the weapons and infrastructure to take over the world. But keeping themselves separate from business and technical applications cannot absolve scientists from blame; after all, scientists are always keen to claim credit for technical or business success.

Wells also showed the experimental process, and a little of the social context of science, most elaborately, if satirically, in *Food of the Gods*. His account demonstrated the hypothetico-deductive method. Redwood investigates growth in a range of organisms by plotting curves and finds that all growth is sporadic; spurts of growth are separated by periods of quiescence. Bacon's principles survive in this establishment of matters of fact, for Redwood is obsessed with his methods and the data he accumulates. He constructs a simple hypothesis to explain the patterns, that a growth-causing substance is manufactured in spurts, causing growth in spurts. The hypothesis at this stage is speculation. To make it stand up, Redwood must deduce consequences that follow if the hypothesis is correct and then conduct experiments to see if his predictions are right.

His first task is to isolate chemical substances from the animal species concerned. If he succeeds in finding the right substance, he must see if it or an artificially synthesised version will cause animals to grow fast. He therefore sets about extracting substances from body fluids and feeding them to animals to see if this happens. He has enough positive success to publish his results in *The Philosophical Transactions of the Royal Society* where Bensington reads them.

Redwood's most suggestive substance is the same alkaloid that Bensington has extracted in his research on brain function. He suggests they collaborate in trying to synthesize this molecule, which can then be tested on animals. They succeed, and the pure form of their putative molecule does cause animals to grow fast. Bensington finds a poultry farm where they can feed the chemical to chicks and measure their growth to produce Redwood's curves. The scientists are stereotypically clueless when it comes to activities outside the laboratory. There is massive growth but it is not confined to chicks: wasps,

earwigs, rats, nettles, and creepers all explode in size. Bensington and Redwood's initial response is that, as theorists, such practical consequences have nothing to do with them.

In some romances, Wells focused on scientific knowledge, the second attribute of science, explaining the science behind the fantastic events he described. He was good at constructing plausible scientific 'patter', convincing because some elements were scientifically correct. When he described the moon or Mars, accounts were based on contemporary scientific theory. Astronomy at the time gave credence to the possibility of alien life forms on other planets, and it followed that human survival on such planets was feasible (Lane, 2005). But Wells focused mainly on the implications and applications of science. It was clear to him that science and technology were going to produce effects on human society, which would not necessarily be desirable. For instance, Moreau and Griffin, the Invisible Man, might undertake their work in a positive spirit of scientific enquiry, but it is all too easy for the work to be misdirected to goals that society cannot accept.

When it came to technology, Wells, like his contemporary, George Griffith, homed in on aircraft and weapon systems and predicted that there would be more wars and greater destruction in the future. Less-than-utopian human beings in democracies would not be able to prevent hyper-destructive weapons being used. *The War in the Air* (1908) ends with the collapse of civilisation in an era of constant warfare. In *The World Set Free* (1914), civilisation survives and prospers, but only after a horrendous nuclear war. Only in this last romance does Wells address the issue that concerned so many other scientific romance writers: the place of spirituality in a world moulded by science and technology. This lack of interest in spiritual matters, and (relative) optimism that science and technology might resolve otherwise intractable socio-political problems, are major differences between Wells and most of his scientific romance peers.

Scientific romance between the wars: resurgent scientific optimism meets philosophical and fictional pessimism

While science had attracted popular support in Victorian and Edwardian Britain, the destruction of the First World War soured public opinion. To counter this anti-science feeling, a number of scientists wrote popular essays arguing a positive case for science, most famously perhaps J.B.S. Haldane with *Daedalus: or, The Science of the Future* (1923). This essay was a paean to the benefits of science, claiming that it was the essential underpinning to technical innovation, industrial production, and economic growth. His most contentious prediction was that artificial culture of human embryos,

ectogenesis, might be possible, embryos which could be further modified by hormone treatment and re-oriented with psychological intervention. Haldane saw all these possibilities as beneficial.

There were plenty of people who took the opposite view. Bertrand Russell fired off a riposte in *Icarus: or The Future of Science* (1924) in which he argued that mankind, given more power with scientific knowledge, would simply have greater opportunities for oppression. More scientific knowledge was no substitute for ethics or reason in the conduct of human affairs, while technology made the world less safe by providing larger forces to apply to potentially bad ends. Scientists naively believed that social conflict was caused by factual ignorance, resolvable by recourse to science, an argument going back to the seventeenth century. But differences in value between groups are seldom based on matters of fact (Dronamraju, 1995; Ezrahi, 1995).

The gap between scientific materialism and spirituality was also widening. Cosmological explanations of the universe, which focused on its mechanics, were now divorced from religious and philosophical explanations, which incorporated meaning and purpose. Writers of scientific romances tried to respond to both the economic and political crises of the interwar period and to the ongoing loss of spiritual meaning in an increasingly godless world (Wells, 1933; Stapledon, 1930 and 1937; Lewis, 1938, 1943, 1945).

Few interwar romances had much to say about the business of doing science, apart from some key scenes in Aldous Huxley's *Brave New World* (1932). As a student, Huxley had been a close friend of the young J.B.S. Haldane and during the Depression he investigated social conditions among factory workers and was shocked at their obsession with escapist Hollywood films (Murray, 2002). He re-expressed these feelings in *Brave New World*, a satire on the future imagined by Wells, using the techniques predicted by Haldane. But where Haldane saw scientific advance leading to a better society, Huxley predicted a totalitarian dystopia, with Haldane's ectogenesis an everyday reality creating human castes, a critical step to producing engineered social harmony. Whereas Wells saw human re-engineering as an ultimate good, despite the horrors and pain necessary to get to an end-state, Huxley imagined there must be a better way to arrive at social harmony and thought the re-engineering process created intolerably hollowed-out humans.

After 1945: The last gasp of the Scientific romance

During the 1940s, American science fiction became more sophisticated in its portrayal of science and absorbed some of the pessimism of British scientific romance. This re-worked genre dominated science fantasy writing throughout the 1950s and 60s. Though most of the generation of post-war British writers

adopted the new mode, a few kept faith with the romance tradition. Among the latter was John Wyndham, who published a string of books that achieved mainstream literary approval, beginning with *The Day of the Triffids* (1951), and continuing through *The Kraken Wakes* (1953), *The Chrysalids* (1955), *The Midwitch Cuckoos* (1957), *The Trouble with Lichen* (1960), the novella *Choky* (1968), and the posthumously published *Web* (1979).

Wyndham, whose full name was John Wyndham Parkes Lucas Beynon Harris, first explored the American pulp magazine market for science fiction, publishing under the name John Beynon Harris, and published two science fiction books in the U.S. as John Beynon. During the war he saw action with the Royal Corps of Signals, experience that gave him material for the disasters in his later stories. He abandoned the science fiction form and deliberately wrote in the romance style of H.G. Wells (Aldiss, 2009). Wyndham's stories are informative about all three attributes of science: its process, product, and social impact. In terms of process, Masen in *The Day of the Triffids* gives a plausible account of analysis of the chemical composition of triffid oil samples to identify the species and locations of plants. In *The Kraken Wakes*, two opposing scientific styles are represented by the geographer Bocker and the oceanographer Matet. Bocker speculates widely from few known facts, while Matet conducts detailed oceanic analyses and is less keen to speculate about what results might mean. Bocker is a romantic while Matet is a bureaucratic Baconian. In dealing with the aliens, Bocker's expansive style proves more useful (although he is pilloried for the extent of his speculation). Wyndham fixes it for Bocker to be right, and the more exciting scientific style wins the day.

In *Trouble with Lichen*, Wyndham explores personal and professional relationships between an older male and younger female scientist, focusing on serendipity and scientific records. She believes the professions, including science, are open for women, but women are missing from the top because of time needed for child rearing. She wants to find a solution to this problem. Both she and her boss notice that the milk put out for the laboratory cat does not sour during thunderstorms. Could this be an antibiotic effect of one of the collection of new lichens that she is classifying? Her boss, who is a biochemist, says he will look into it but says nothing further until she asks him about it months later. He stonewalls and she is suspicious. She takes another sample of the lichen, keeping its existence secret so that she can work on it privately. She confirms that it is not an antibiotic, but it has anti-aging properties. She guesses he knows this as well but is keeping quiet. Eventually they agree to co-operate in the search for a successful anti-aging treatment.

In *Web*, a young pathologist uses her background knowledge of insect and other invertebrate pests to speculate in evolutionary terms about how a new spider species may have developed. She imagines that with its advanced social understanding this species may be able to use its silk to construct devices as elaborate as fishing nets. She renders the suggestion plausible in the way that Darwin made unlikely ideas plausible, by showing that remarkable things have already happened; spiders already use their silk for a wide range of phenomena from weaving cocoons to building elaborate webs.

Wyndham also invents a fair amount of plausible fantasy scientific knowledge. He employs H.G. Wells's technique of using fantasy facts based on readers' general understanding of real forces, chemicals, and unusual animals and plants, with alien science that takes off from this real or plausible scientific data. But as with most scientific romances, speculation about the implications and applications of science lies at the core of Wyndham's stories.

While Wyndham carried on with the romance tradition, some British writers adopting the science fiction template were keen to present contemporary scientific knowledge and process, as well as speculative futurology. For instance, in Fred Hoyle's *The Black Cloud* (1957), a mysterious cloud approaches the solar system and will plunge the earth into darkness for four to six weeks as it moves between the sun and the earth on its way through. Such an event would be disastrous enough, but the cloud does not pass; it slows down and settles round the sun, interfering with earth weather and environmental systems.

Hoyle imparts real information about astronomical instrumentation and technique, providing diagrams in the text and demonstrating calculations in footnotes. He makes use of the vast new computing power that was becoming available at the time, and of extensions to radio communication technology that were emerging from studies in radio astronomy. The scientists predict the behaviour of the cloud as more data become available, but they fail to provide accurate forecasts, because the cloud repeatedly upsets their assumptions about its basic properties. The technology of radio communication with the cloud is accurately portrayed, and contemporary astrophysical science is expounded at some length to explain what is going on.

This correct, up-to-the-minute, scientific knowledge moves the story into science fiction, as does the success of the scientists in dealing with the threat, overcoming the wrong calls made by ignorant politicians. It is the scientists who save the world; scientific knowledge is put to good and fruitful use. A story about the business of doing science is well told here, illustrating the strengths of scientific practice but also its weaknesses. What may reduce the

impact of Hoyle's effort is the dense packing of scientific knowledge and ideas, slowing up the story in chapters of almost pure exposition, which may only appeal to those readers already familiar with that knowledge.

5. Popular Fiction in the Mid-Twentieth Century
Scientists as 'New Men'

Science and the British collectivist state from the 1930s to the 1960s

We have seen that elements of the business of doing science appeared in early utopias and satires, in a small number of nineteenth- and early twentieth-century literary novels, and in some scientific romances. This limited coverage is disappointing. But between the 1930s and the 1960s, a small group of British writers did focus on the business of doing science. Their work hovered in the uncomfortable gap between literary and genre fiction and has not survived well (Russell, 2009, Gratzer, 1989).

These authors had active writing lives in a collectivist economic era, when state intervention dominated the British economy. This economic collectivism was a reaction to the failures of free-market economies, which had led to the Wall Street collapse of 1929. The British response was to develop a centrally planned economy dominated by big industry, the military, and government, a situation that provided excellent opportunities for scientists. But by the late 1960s, the inefficiencies in this state-sponsored corporate capitalism were producing its slow collapse, and since the early 1980s, it has gradually been replaced by economic liberalism in which markets are left relatively free of state intervention.

The most important place in Britain for science during the collectivist era was Cambridge University. Although university-based pure research was only a small part of overall scientific effort, Cambridge scientists used their shared background with the British governing class to make a convincing case for the importance of basic science in technological development and industrial success, something the scientific community had long been arguing. Governments started to agree and began to expand funding for basic science, although university scientists often continued to despise work in technological development.

Despite their reluctance, academic scientists made extensive contributions to the Second World War effort when commandeered to do so, although these military projects depended less on pure science than some of the commandeered personnel have claimed. After the perceived success of British military technology in the war, much post-war scientific research and

development remained defence-oriented. But by the late 1960s, Britain's imperial illusions were over and the collectivist economic era drifted to an end, reducing the demand for science and scientists in defence and in industry in general (Bud and Gummett, 1999; Edgerton, 2004, 2005; Hartcup, 2000; Wersky, 1978).

Throughout this period there was a largely positive attitude to science in factual news media and British cinema films about scientists also portrayed them positively, as did the novels considered here (Jones, 1997, 1998, 2001). Science was seen as a valuable activity; the public believed that science and technology contributed significantly to their wellbeing despite the dent to optimism produced by two global wars in which science had been a source of destructive weaponry. Science had fallen sharply out of favour after the First World War, so it was a propaganda triumph for government and the scientific community to be able to reassert the benevolent value of science after WWII, despite the continued emphasis on weaponry in the ensuing Cold War.

The mid-twentieth century writers and their books

During this period, several scientifically educated authors explored the machinations of scientific careers and showed how scientific knowledge was constructed. Between them they wrote fourteen novels in which the business of doing science was central. They were A.J. Cronin (1896-1981), E.C. Large (1902-1976), C.P. Snow (1905-1980), Nigel Balchin (1908-1970), and Harry Summerfield Hoff (1910-2002), writing under the pen name William Cooper.

They all had multiple careers as writers, scientists, administrators, or businessmen and wrote at least two novels with scientific themes. All came from less privileged backgrounds, except for Large, who was privately educated but rebelled against family pressure to become a lawyer, taking up an apprenticeship and engineering degree. Not surprisingly, the heroes of these novels are often Wellsian characters from the lower middle class who make good through careers in science. They are the successful 'New Men' of the titles of books by Snow and Cooper.

A.J. Cronin's books with science themes started with *The Citadel* (1937), a fictionalised account of his experiences in research-oriented general practice, continued with *The Green Years* (1945), covering the childhood of another fictional *alter ego*, Robert Shannon, and concluded in *Shannon's Way* (1948), with his story after he finishes his medical education and starts a career in biomedical research (Anon, 2007; Cronin, 1952; Hodges, 2006).

E.C. Large published three novels. In the first, *Sugar in the Air* (1937), Charles Pry develops an industrial process to produce carbohydrates from carbon dioxide. The book is satirical about industry, industrial science, and British

politics. His second novel, *Asleep in the Afternoon* (1938), has fun at the expense of several aspects of British culture in the 1930s. The science is fantastic with a modified hearing aid causing users to sleep with intensely erotic dreams. He later wrote another story, *Dawn in Andromeda* (1956), a fantasy in which God relocates a sample of humanity on an uninhabited planet (Colhoun, 1993; Hardwick, 2001).

C.P. Snow began his career as a Cambridge scientist. By the end of the thirties, he had written *Strangers and Brothers*, the first of a cycle of eleven novels about leading members of society, many of them academic scientists with connections to the governing class. The books with scientific themes began with *The Search* (1934), a strongly autobiographical story of a lower-middle-class provincial boy undertaking doctoral research at Cambridge but lacking the personal and technical skills to get to the top. The other science-containing novels belong to the *Strangers and Brothers* series. *The Masters* (1951) is set at a Cambridge college and describes the struggle of the fellows to elect a new Master, with a secondary plot as the college extracts a large endowment from an industrialist. *The New Men* (1954) concerns British physicists in the development of nuclear weapons during the Second World and Cold Wars with a strong sub-plot on security and espionage. *The Affair* (1960) is again set in Snow's fictional Cambridge College, the central issue a hearing among the Fellows about re-instating a junior member dismissed for scientific fraud. The *Corridors of Power* (1964) follows the career of a politician, Roger Quaife, who wants Britain to give up its independent nuclear deterrent. There was a hard-left group within the real Cambridge science community of the 1930s and 40s from which key figures opposed to Britain's nuclear deterrent emerged in the 1950s. Their leader was Patrick Blackett, and Snow modelled the fictional Francis Getliffe's position on nuclear deterrence in *The New Men* and *The Corridors of Power* on that taken by Blackett (Brand, 1988; Weintraub, 2006; Paul, 2000; Nye, 1999).

Harry Summerfield Hoff (under the pseudonym William Cooper) wrote his first book with a science theme, *Struggles of Albert Woods*, in 1952. It is the story of a bright provincial boy who makes a life in science, starting as an innocent idealist and slowly understanding the patterns of social influence that govern careers in science. Cooper's second science-themed book, *Memoirs of a New Man* (1966), is narrated by Jack Carteret, another lower-class provincial boy who has become an Oxford scientist with a part-time position on the electricity-generating National Power Board (NPB). There are twin plots involving the challenge to his college to abandon its admissions policy of only accepting science undergraduates and the place of scientific research at the NPB (Bradbury, 2006; Taylor, 2006).

Nigel Balchin's books with science themes include the *Small Back Room* (1943), narrated by Sammy Rice, a scientist commandeered into war work, with an artificial foot, a drinking problem, a difficult relationship with his girlfriend, and doubts about his non-combatant role. He assuages these personal issues by heroically disarming a delayed fuse bomb. *A Sort of Traitors* (1949) pits scientific freedom against political constraint. Professor Lucas Sewell attempts to publish the results of a lifetime project on protective antibodies, but is stopped by a government security clampdown because the work has implications for biological warfare. Balchin also wrote *Kings of Infinite Space* in 1967, which grandiosely considers what advances in science and technology mean for the human condition through the involvement of a British physiologist in the American space programme (Bunn, 2001; Hooper, 2007; James, 1979; Rowland, 2006).

These novels contain a great deal about the business of doing science, exploring what research is actually like, the status of scientific knowledge, the necessary administrative machinery between science and its application, the problems of doing research, and the possibility of applying scientific knowledge ethically for the benefit, or otherwise, of society (for more detail, see Russell, 2009).

The scientific workplace: the mind, the team, and the liaison with the outside world

These stories show that the business of doing science is intellectually difficult and involves laborious practical work. Scientific practice is tough and demanding. Much of the detail describes applied research, which is both easier to explain and constitutes most scientific work done. In two of Cronin's books, *The Citadel* and *Shannon's Way*, enthusiastic general practitioners undertake medical research on disease causation in their spare time although they find this extremely hard. Shannon also learns the hard way that publication is essential in order to take credit for a new scientific fact.

While medical research is one category of applied science, another is industrial technology. In Large's *Sugar in the Air*, Charles Pry is appointed a works engineer, initially doing experiments designed by an academic expert in the chemistry of carbohydrates, hired as a consultant to examine a new process for sugar synthesis and production. Pry proves to be an effective technologist, good at consistently varying conditions to get improved performance and having the Eureka insight that power station flue gases might contain high enough concentrations of carbon dioxide to make production viable.

Industrial research and development can involve experiments conducted on a large and dangerous scale. Snow's *The New Men* contains dramatic accounts of the concentration of radio-isotope Uranium 235 in the nuclear weapons programme and its reaction in an atomic pile to generate plutonium. Snow's scientists do a test run on the pile in March 1944 but fail to produce a chain reaction. Rebuilding the pile takes six months before it successfully generates plutonium. Some of the team want to stop and go forward slowly, but others want to experiment with bomb-making, taking the risks of handling the dangerous materials themselves. There is a major accident, but even those scientists who suffer from radiation sickness want to go on.

These stories demonstrate that science is a team process and research performance depends on leadership and team interaction. Assembling and running teams is a sophisticated issue. Most of the fictional teams are in pure research laboratories with three categories of scientific player: team leaders, journeymen scientists who do much of the intellectual and some of the practical work, and technicians who undertake most of the practical work.

A research leader does not have to be brilliant; the key to success can lie in effective management, as Albert Woods in Cooper's *Albert Woods* and Arthur Miles in *The Search* discover. Everyone accepts that teams have to be managed, which gives leaders the right to corral their juniors, even if their own work is not inspired. Snow's Miles makes a distinction between technical problem-solvers and creative conceptualists. He also believes left-wing scientists favour an 'industrial' model of laboratory organisation, with pre-specified problems tackled by specially constructed project teams, while the more conservative believe the best work is done by allowing individual leaders the freedom to pursue their own ideas.

The young Miles fantasizes about running his own laboratory and believes the best leader is an effective manager, but when he gets involved with setting up an actual research institute, he finds the process highly political. Other scientist characters also think research teams should be assembled on rational principles and are intensely disappointed by what happens in practice. Miles finds that members of the Institute Planning Committee come with a variety of competing interests, which all have to be negotiated and compromised in building a team.

The most junior members of research teams are technicians. In *The Citadel* and *Shannon's Way*, conveniently under-employed female partners develop technical proficiency. Some professional technicians get stuck with the role and resent it (*Green Years*) while others are proud of their expertise (*A Sort of Traitors* and *Small Back Room*). It is even possible to move up from being an

applied industrial technician to university research scientist, though it is likely one will still work on applied problems and it is important to avoid the distraction of teaching (*Memoirs of a New Man*).

Between the leaders and the technicians, laboratories are populated with journeymen scientists (*Woods* and *Search*), and in *Traitors* there is even a woman. She is not thought suited to science, though she makes a good experimentalist—a fictional description that reflects attitudes towards women in laboratories at the time (Horrocks, 2000). Permanent journeymen stand in contrast to the bright stars who are on their way up and have hopes of leading their own teams.

Applied research (development) is validated when applications work in practice, but no such simple test for the truth of new scientific knowledge exists. Young scientists accept that scientific ideas are true because they are told so by trustworthy sources, their teachers (*The Search*). Non-scientist friends point out that laws and theories only provide plausible stories that fit the facts, merely showing that they might be true. Nevertheless, Miles extends his belief that science produces reliable knowledge to argue that scientists deserve to have special influence in the world. Again, non-scientists disagree, pointing out that scientists have human failings and do not necessarily possess the wisdom to use their knowledge well.

Universities have to undertake both teaching and research, and the relation between these two activities can prove uneasy. Scientists working at universities consider time devoted to teaching wasted because it interferes with research (*The Search* and *Memoirs of a New Man*). In Snow's *Masters*, the victory of a scientist over a humanities scholar in election to a college headship symbolizes the shift to science and research at the expense of humanities and teaching in the mid-twentieth century university.

In the collectivist era, there was a need for mediation between the collaborating institutions of science, industry, the state, and wider society. Such mediation was often organized through management boards with mixed memberships that included scientific specialists, other stake-holding interests, and lay representation. In theory, such organizations could debate controversial issues involving the multiple interests and expertise of the participating groups, and arrive at rational conclusions. In practice, the boards were often dysfunctional, and the reasons are explored in *Sugar in the Air*, *The Citadel*, and *Memoirs of a New Man*. The problems include misdirection of scientific staff by boards that do not respect them, failure to co-ordinate professionals from very different backgrounds (scientists, engineers, and civil servants), and considerable reluctance by non-scientists to

give scientists managerial or policy roles. The more naïve scientists suppose that objectivity in science gives them superior powers of judgement, but those scientists who succeed as 'men of affairs' are acutely aware of the need for good human relationships and the importance of politics in research and in liaising with the outside world.

The ethical responsibilities of scientists

With science at the centre of major areas of public policy, issues of how scientists should behave became critical (Resnik, 1998). The majority of fictional ethical dilemmas concern the applications of science in politics and culture, but there is also discussion of research practice in terms of scientists' responsibilities in safeguarding the integrity of their work.

The problem of suspected fraud is the main theme of Snow's *The Affair*. An obvious motivation for fraud is dishonesty, which is clearly a moral offense, but in *The Search* Snow suggests other factors can drive honest scientists to commit fraud. Promising lines of research often have to be abandoned in the light of results that do not fit. But some committed scientists refuse to accept the counter-evidence. Cooper's Albert Woods commits fraud for a reason often given in reality: a difficult line of work must eventually come out as the researcher intends (Medawar, 1991).

While high standards of honesty are expected in the laboratory, some fictional scientists like those in *Sugar in the Air* and *Small Back Room* take a limited view of the extent of their ethical responsibilities beyond the lab. In business or defence contexts, these characters are quite happy to 'spin' or disregard results, while others are reluctant to make such compromises. Similar ethical problems may emerge when scientific decisions are presented to a wider public and different political standpoints challenge the straightforward honesty of the scientist, as we see in *Memoirs of a New Man*.

Generating electricity and manufacturing sugar are clearly not unethical processes in themselves, but some potential applications of science present direct ethical dilemmas. These are explored in books such as *Albert Woods*, which deals with work on chemical warfare, and *A Sort of Traitors*, in which new knowledge has defence implications not envisaged by the researchers. Many dramas and films have dealt with scientists' ethical responsibilities in the development of weapons of mass destruction (Brouwer, 1988; Hye, 1996; Shepherd Barr, 2006). Two of Snow's novels, *The New Men* and *The Corridors of Power*, also address the issue head on, reflecting quite closely the actual pattern of events in Anglo-American nuclear collaboration and competition in the 1940s and 50s. Political positions, pacifist attitudes and Cold War spying all play their part. This leads to unresolved tension over the

ultimate authority of science: does it derive from the employing nation state or does it come from the principle of the free pursuit of ideas? Fictional British physicists developing the atomic bomb face an ethical quagmire from which they escape with fairly low-grade pragmatic decisions. In the Cold War, many of them tire of dealing with public affairs and want to get on with their research. Having grappled with the knotty problems of becoming men of affairs, Snow's, and to a lesser extent, Cooper's scientists are ready to retreat from the intractable difficulties and return to scientific questions, which seem more easily solved.

6. Conclusion

From this three and a half century sampling of British fiction dealing with science, it is clear that its first attribute, the business of doing science, is a viable but surprisingly little-employed theme in fiction. The majority of texts dealing with science were popular fantasies, initially utopias and satires, latterly speculative futuristic fiction. Most of these stories focus on the future implications of a small number of big scientific ideas: notably evolution theory, solar and planetary astronomy, entropy, the fourth dimension, and the nature of time. The ideas are seldom explained in detail and many of the extrapolations are scarcely plausible. But the main implication is clear: readers find big and often surprising scientific theories exciting in and of themselves and are much stimulated by the implications of such theories for the organization of society, technological innovation, the future biology of human and alien beings, and understandings of the meaning of life and our place in the universe. These are stories about ideas and their implications, broad-brush treatments of scientific knowledge (the second attribute of science), with most of the emphasis on scientific implications and applications (the third attribute). Such fantasies are not known for sophistication in character development, so the scientist characters tend to be stereotypes drawn from ancient, but surprisingly resilient, literary myths.

While early utopias and satires focus on the impacts of science, they also explore some aspects of the first attribute of science, the business of doing it, serving as positive or negative propaganda for this new way of understanding nature. Much is made of epistemology: what are the experimental philosophers doing and are they and their methods generating reliable information and knowledge? Another key theme is whether the aim of investigation should be theoretical explanation, the light of science, or practical technology, its fruit. Subsequent social and philosophical history gives a firm answer: science's claim to significance lies entirely with light.

Fruit is for technologists and is considered dependent on, and subservient to, that light.

Until recently, science and scientists in mimetic literary fiction were harder to find. Plausible, non-mythological, scientific characters (in terms of personality, behaviour, and social role) feature in a small number of Victorian and Edwardian novels, although they tend to show stereotypical antisocial tendencies at least partly drawn from literary myth. Where the utopias and satires focused on epistemology and purpose, the literary novels concentrated on the wider sociology of the emerging profession and dealt very little with how science is done.

From the ranks of both fantasies and classic novels, a small number have the business of doing science in the foreground. These include *Jekyll and Hyde*, *Dracula*, *The Coming Race,* and possibly *Frankenstein* and *The Food of the Gods*, with *The Lost World* on the periphery. From the literary cannon, *Two on a Tower* and *Born in Exile* should clearly be included here, and *Wives and Daughters*, *Heart and Science*, and *Tono-Bungay* might also be added.

The fourteen popular novels that do focus on the business of doing science and were published in the much narrower period from the 1930s to the 1960s greatly outnumber those from different genres across the longer time-span. This demands some explanation, and I tentatively suggest that it has something to do with the collectivist and social democratic context of this short period in British social and political history. But while that specific context may have been the stimulus for the novels, their number and the depth and sophistication with which they explore the business of doing science confirms that this is a theme which can be dealt with comprehensively and well in a fictional context. It will be interesting to discover whether the current wave of novels with science themes that began at the very end of the twentieth century proves as comprehensive in its treatment of the business of doing science and can be ascribed to any specific aspects of contemporary culture.

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