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Introduction

A brain surgeon stands confronted by a violent man. The aggressor's mental state is exacerbated by the fact that he is slowly tipping over the edge of a degenerative neural pathology. What specialist knowledge can our scientist use to defuse the attack? What facts and understanding about the mind can he draw upon to salve this example of the human condition? The answer is none at all. Only his daughter, a poet, can do so.

This situation forms the climactic scene of Ian McEwan's recent novel *Saturday* (2005). The surgeon's name is Henry Perowne, and his daughter is Daisy Perowne. Daisy calms the assailant, Baxter, and saves her family by reciting for him the nineteenth-century poem 'Dover Beach'.

McEwan's choice of poem is a significant one. It was published by Matthew Arnold in 1867 and famously spoke of the 'melancholy, long, withdrawing roar' of the 'Sea of Faith'. This was widely interpreted at the time (and since) as a response to the challenge posed by science to religious belief. The old, comforting certainties of purpose and the human place in nature were slowly being eroded by evolution, energy physics and other sciences. More broadly, Arnold's poem was a reflection on a cultural clash not just between science and theology but also between science and all of the arts. Theology and the 'Greats' – classical languages and literature – had until then formed the backbone of a proper English education, but now scientists, emboldened by their recent successes, demanded that these should be replaced by an education in science. Arnold engaged in a public and long-running debate with the prominent scientist T. H. Huxley over this issue. Historians agree that Arnold was willing to part with a belief in the literal truths of Christianity; what he was not prepared to relinquish to science was the pre-eminent role of the literary arts in shaping human values and culture.

Perhaps it's no surprise that in the critical moment McEwan goes with Arnold and gives literature, not science, the role of salvation. He is a novelist after all, and if science could provide all the answers that matter in life then he would be out of a job. Still, literature doesn't win the battle straight; nor is the situation even quite a battle between the two. Following Daisy's successful recitation, scientific bamboozlement and straightforward violence are required to secure the safety of the household. Baxter is lured upstairs by Henry with a promise of a cure for his disease, and then booted down them.

Yet McEwan is clearly seduced by the science. The scientific elements of the book are meticulously researched. The description of Huntingdon's Disease, for example (Baxter's condition), is accurate, and a scene of neurosurgery is described in considerable and very technical detail. A range of other neurological and medical conditions are presented in technical terms. These diagnoses are not coldly opposed to the understanding of humanity that is more usually claimed by the literary arts; rather they are integrated into the characters as features of their humanity. A quotation from Darwin is also treated as a serious object for philosophical contemplation. Science even affords Henry Perowne a redemption for his violence. After Baxter's tumble down the stairs Perowne is called upon by the hospital as the person best able to operate upon him for the cranial trauma he has received. This he does, putting aside his animosity and guilt in favour of the higher call of medical service, and making good his assault with scalpel and needle. All in all, McEwan gives a sympathetic portrayal of Henry Perowne, scientist, a character whose political apathy and apparent self-satisfaction – even smugness – were anathema to many of his readers.[1]

Thus science has a significant place in McEwan's understanding of contemporary experience. The critical success of *Saturday* and its excellent sales figures demonstrate that the same was true for his readers – that it addressed questions many of them found interesting and worthwhile. The interpolation of science into the big questions of life obviously worked for them. Clearly, many of them cared about the relationship between different types of knowledge, the artistic and the scientific. The implicit, overarching question of the novel would seem to be this: if science provides facts and literature values, how should we integrate these apparently different types of wisdom in order to live meaningful and contented lives?

McEwan's book gives the lie to an argument made fifty years ago by the physicist and novelist C. P. Snow (1905–80). Snow claimed that participants in science and literature had no knowledge of one another's

fields, and worse, that the writers in particular were almost guilty of taking pride in their scientific ignorance. Snow and his 1959 lecture on the 'two cultures' is an obligatory but uninspiring inclusion in any introduction to the field of literature and science. In response to that lecture Snow's nemesis, the literary critic F. R. Leavis (1895–1978) loudly and publicly scoffed at the value of science, and denounced the quality of Snow's novels too for good measure. However, the spat was very much of its day. Its participants were not so much claiming future ground as rehearsing Victorian arguments from the early days of their careers.[2] The relevance of the debate in relation to the field of literature and science today is questionable. C. P. Snow is a straw man who has been so comprehensively pummelled that every last shred of his stuffing has vanished in the wind.

Yet the confidence of academics that literature and science are compatible reaches only so far. When I teach literature and science, as I have done for some years now, I encounter a persistent undercurrent of doubt among students that the two really go together. Isn't science about fact, while literature is ('only') about opinion? Their doubt comes in large part because, despite attempts at broadening the curriculum, students in the UK are still essentially asked to choose between the sciences and humanities at the age of fourteen. The sciences, especially physics and mathematics, retain an aura of exclusivity, and although some actively choose the humanities, for others it is regarded as the leftover option remaining to those incapable of doing science.

The following section, 'Shared Ground for Literature and Science', introduces some reasons why humanities students need not be afraid of science. It outlines some common arguments put forward as to why science and literature are not compatible, and then takes issue with their underlying assumptions. The section after that, 'Historicising Literature and Science', gives a very brief overview of the two fields in the past three hundred years or so, and makes the case that science and literature have had an especially large amount to say to one another in former times. It explains the nature and importance of historicised reading, and claims that a contextual reading of novels involving science is a good way of understanding science of the past. Although science and literature are arguably further apart today than they have been historically, both remain human activities undertaken for very human motives. Both are part of a shared cultural spectrum of representation, truth and value. 'Using Form to Study Literature and Science' outlines the methodology taken in this book to place the two fields on that shared spectrum. A concluding discussion of value, focused on the present day, suggests

that novels were and remain a cultural method of working through the principles that underlie science, and that by paying attention to the form of novels we can understand and even participate in the construction of the meaning of science.

Shared ground for literature and science

Let's begin with the common undergraduate belief that science is about objective facts while literature deals in subjective opinions. The idea can be dispatched in a number of ways. For a start, science is all about persuading others that certain hypotheses are true: that they should be elevated to the status of fact. Persuasion is primarily an art of language and literature, and so the presentation of an argument – that is, its literary form – is central to its credibility. No fact will be agreed as true unless it is presented in an acceptable style. At different times, different literary styles have been seen as persuasive and therefore desirable. A passively phrased account ('such-and-such was done…', 'it was seen that…') would not satisfy the earliest gentlemen of science, the creators of a plain style of science in the seventeenth century. For them, scientific knowledge was intimately connected to the gentlemanly trustworthiness of the reporter. *Who* did this? *Who* saw this? Was it someone they could trust? Today, in direct contrast, scientists are encouraged not to use the active voice. They are trained to avoid using the first person in their accounts, as this sounds too subjective by modern standards. Even today, in scientists' preference for the rhetoric of the passive form, the processes of persuasion are very much mixed up with ideas about literature and language. Scientific disputes continue to be conducted through literature, mostly in journals of science and sometimes also in the wider media. These disputes are never 'purely' scientific; they are always language-based processes that cannot be reduced to a non-linguistic form.

Philosophical and sociological research into the nature of representation has also blurred the boundary between what have traditionally been regarded as objective and subjective knowledge. This work has emphasised that there can be no such thing as an objective scientific fact that exists without representation, and that representation may be defined as a subjective phenomenon that (for our purposes) very often involves the use of language. We simply cannot make sense of objective facts without subjective representations – images, models and metaphors that make them real to us. For example, Robert Boyle developed his work on the pressure and volume of gases by representing the air as

a spring – the very piece of equipment upon which many of his experiments depended. Similarly, Richard Dawkins exhorted his followers to think of the 'selfish gene' as a way to understand its ruthless quest for replication down the generations. Such metaphors and images act as frames for knowledge. They allow us to understand scientific ideas, and they actively affect our understanding. As such, scientific facts are always embedded in their representation, a phenomenon that is in large part subjective and literary or artistic.

The argument about representation has sometimes been exaggerated by those who wish to defend the objective purity of science. They claim that this approach reduces all scientific facts to the level of fiction – that it implies the selfish gene is just as much a made-up story as is the Selfish Giant. This criticism fails to understand the subtlety of the representation argument. The argument does not entail that genes are not real without representation, but rather that *they are not real to us*, or *not real in any meaningful sense*. Only when they have words and images attached to them are they meaningful to us – and these words and images bring along a whole host of allusions, history and connotations that themselves become part of the representation as the science is further developed. Sociologist Diane M. Rodgers refers to this process as a 'legitimation loop'. First, in her account, an image from culture is used to describe nature. Transformed thus into fact, it acquires additional authority when it is taken as a representation from nature to describe something in culture, and so on back around the loop.[3]

A good example of the representation argument relates to the metaphors of inheritance. Genes were not real – not facts – for anyone in the nineteenth century. Charles Darwin did not sit scratching his head as he wrote *On the Origin of Species*, thinking 'If only I knew about genes this would all make sense!' Rather, he had a consistent and coherent representation of the 'facts' that made sense in his own context. This consisted of an appreciation of nature's variety, and an idea of nature as 'selector'. This latter was an arresting metaphor, and has provoked intense scrutiny and discussion ever since. It carried theological overtones (nature as judge or designer) as well as images from economic theory (Adam Smith's 'hidden hand' of the market).

No one ever found a neat blob under the microscope labelled 'This is a gene', but genes are today 'facts' for us, and they are represented through those older metaphors of inheritance as well as through the evocative visual model of the double helix and ascriptions such as 'selfishness'. Most importantly of all, the gene is conceived as a unit to store and process information in top-down fashion – a representation that can

only make sense to those of us living in the information age of computers.[4] The process of nucleic acid transcription (genetic coding) existed before we discovered it – but 'genes' did not exist for us as humans in any meaningful way until there was a way to represent them. Indeed, it is possible that in fifty or a hundred years' time we will no longer see aspects of bodies and behaviours as individual properties coded top-down from within, and there may be little or no talk of 'genes' – which would be replaced with a different word for a new phenomenon.

Thus the argument about representation does not state that science is 'merely fiction'. Rather, it recognises the contingent construction of scientific representation and the embedding of its symbols in the language and culture of its time. This is what makes the literature of science such a fascinating area of study. Science cannot be conducted without language, and language is not a neutral tool. It actively shapes knowledge just as much as does the decision to dissect this animal, use that microscope, perform this test, and so on. Ultimately, anything discovered in science must be described, and because of the stickiness of metaphor that description builds further implications into our picture of the world and ourselves. In fact, rather than implying that things are discovered and then described, it would be better to say that language helps to construct the discovery in the first place, since no scientist can think through the process without the words and images of their culture. Working with language and metaphor is just as much of a method for making knowledge as that which occurs in the more familiar laboratory environment of glassware, Bunsen burners and chemicals. As such, some of the work of science is done by writers and readers of science literature, as well as by the men and women in white coats and their historical forebears.

A neat distinction between dry objectivity and emotional subjectivity also breaks down when one considers the human identity of scientists. Many of them – perhaps most – go into the laboratory or field in the hope that science actually answers, or attempts to answer, many of the same deep questions as do literature and philosophy. We humanities scholars do ourselves no favours if we overlook the passion, curiosity and awe that mark science at its best. Barack Obama, noted for his rhetorical success, knows the power of science to inspire and chose the NASA programme to capture his electoral message of hope:

> Nothing symbolises [science and technology] more than our space programme ... I grew up in Hawaii, and I still remember sitting on my grandfather's shoulders as some of those astronauts roared in ... I

> remember my grandfather explaining to me, this is what America's all about: we can do anything when we put our mind to it ... that sense of possibility, and always reaching out.[5]

The most important human motivations to do science aren't so far away from literary ones: they are to answer life's big questions. The following three paragraphs suggest some of those big questions, familiar from myth and literature, along with an extremely brief selection of their scientific answers.

The biggest question that humans ponder is probably: 'Why am I here?' or perhaps: 'How did I get here?' The most ancient literary texts – holy books and myths – set about answering these mysteries. Scientists have also been inspired to answer them on many levels, from the big bang to the story of evolution. Indeed, some of their conclusions echo the earliest texts. The Earth's age is often compared by scientists to a 24-hour clock, according to which analogy humans appeared at less than one minute to midnight. The temporariness of this image echoes many insights from literature, such as the Bible's Psalm 103, vv. 15–16: 'As for man, his days are as grass: as a flower of the field, so he flourisheth. For the wind passeth over it, and it is gone; and the place thereof shall know it no more.' In later chapters we shall encounter some nineteenth-century novels of ancestry – *Daniel Deronda* and *The Water Babies* – that answered this question of origins from a Darwinian perspective. Even Richard Dawkins, infamous opponent of all that is untestable by science, is aware of the value of science in speaking to our desire for a genesis account. His recent book *The Ancestor's Tale* (2004) is an explicit attempt to reconnect science with its motivating quest for myth. Although non-fictional in essence, it is written as a series of stories. Based loosely on Chaucer's famous tale of pilgrimage, it aims to evoke the reader's personal sense of wonder and connection with the precursors of humanity – their own forebears.

Is life just a series of chances? This question is another deep motivation for human endeavour in all fields, and for two hundred years Isaac Newton was considered to have answered it with a definitive 'no'. He argued that everything was potentially as predictable as a game of billiards, where one can know exactly how one ball will bounce off another. People found this image of life – ordered and rational – very reassuring. By the late nineteenth century, however, the laws of nature, although no less certain in their effects, appeared to be much less certain in their predictability or in their justice. The weak were killed off, seemingly at random, by natural selection. The Sun would run out of

fuel and progress would cease. This pessimistic sense of nature's laws lay at the heart of Thomas Hardy's novels, with their oppressive presence of fate and catalogue of unlikely coincidence. In the early twentieth century, quantum physicists suggested that there was even more chance to everything than had previously been suspected. The butterfly effect, although not strictly or uniquely related to quantum physics, later came to stand as a popular image for this sense of uncertainty. The name refers to the possibility that something as tiny as the flap of a butterfly's wings might ultimately redirect the course of a hurricane, via a long and random series of cause and effect. Don DeLillo's sprawling novel *Underworld* (1997) is perhaps representative of this latter trend of causal uncertainty. It begins with a baseball match (based on real life) in which a ball was famously hit into the crowd. This event, reminiscent of an atomic particle pinging off at random, forms the source of a rambling chain of connections, personal and national, that ramify through the rest of the novel.

Another perpetual motivator for scientists and writers concerns the essence of our human nature. Do we have it in us to love? Or are we always motivated by base concerns? Studies in evolution have provided a basis on which to discuss this question, with evolutionary psychologists claiming that even apparently loving and altruistic traits are merely acts calculated to improve our reproductive chances in the long run. Many critics reject this answer to the question of human nature as too cynical, but they would be mistaken in thinking that science is unique in expressing such pessimism. Novelists too have created equally bleak depictions of human nature. Dostoevsky's antihero in *Crime and Punishment* (1866) commits murder with no seeming motivation, and was reviled by contemporary critics for his nihilism. Dostoevsky's novel ultimately gestures towards Raskolnikov's redemption, but no such resolution exists for the emotionless figure at the centre of Camus's *The Outsider* (*L'Étranger*, 1942). Meursault explicitly eschews remorse for the murder he has committed and, facing his execution, he identifies his amorality with that of the universe: 'I opened myself to the gentle indifference of the world. Finding it so much like myself – so like a brother, really – I felt that I had been happy and that I was happy again.' Thus novelists and scientists have been motivated by the same questions, and have come up with similar answers.

Even if the motivations of science and literature are similar – the big human questions – some might contend that there is an aesthetic difference in their *outputs* that places science in a different sphere to literature. Science, such a person might claim, is not written in a 'literary

style', and therefore the key tools for analysing literature are completely wasted on science. But what is this 'literary style' that precludes scientific writing from its ranks? Most of us have given up on the imperious notion that there exists, somewhere in an ivy-clad college, a library full of dusty books that together constitute the Complete Works of Proper Literature. So why do we still sometimes baulk at counting genres of science as literature? If one had to pin the blame on one single candidate, it would probably be F. R. Leavis. Leavis was soaked in Cambridge's academic culture from his school days, eventually winding up as a tutor at Downing College. He was keen to infuse the study of English literature – then a new area of academic scholarship – with the gravity and seriousness that were normally accorded to such traditional Oxbridge subjects as the classics. The very title of Leavis's best-known work on the English novel, *The Great Tradition* (1948), reveals a lot about his approach to literature. It was about selecting books according to their formal and moral properties, as defined by Leavis's personal preferences. But we are under no obligation to accept his definition. Today, there are no problems in taking seriously all kinds of authors and genres that would be quite alien to Leavis: 'proper' literature is no longer exclusively white, European or American, heterosexual and male. If we can dispense with these norms to include what they leave out, then why not take scientific literature seriously as well?

One should also note that the 'absence' of style is a style in itself, just as a person who claims to dress with disregard to fashion is in fact making a very powerful fashion statement. The story of how the 'style-less' style of science writing came about, circa 1700, is in fact an intriguing one, and is told in Chapter 1. It was described at the time as a masculine, vigorous and distinctively English type of literature. So this clearly *was* a style, and a very interesting one at that. In the present day, there is no single 'scientific style', but rather a multiplicity of scientific genres. These include experiments written up in journals, articles in the press and other media, popular books by scientists and books on science by non-scientists. Some are intended to be beautiful; some are intended to convey 'facts' as quickly and concisely as possible and some are designed to provoke critical scrutiny of the actions and assumptions of scientists. A person might perhaps still try to cling to the idea that amongst these styles is the true style-less style of science, and that none of the others should be counted as real science – only as its dissemination. But even the driest experimental account is susceptible to a literary analysis. It is meaningful only within a whole structure of other meanings, which it is the task of a literary critic to uncover. These include codified accounts

of action, a shared education, and, at the highest level, a whole structured and meaningful universe held in common by writer and reader.

In summary, the literary elements of science are integral to its practice. Science cannot be neatly characterised as 'objective' in contradistinction to the 'subjectivity' of literature, and the pursuits of both science and literature serve many of the same deep human desires. A number of conclusions concerning the relationship of literature and science arise from these arguments. One such, a precept that firmly underpinned my own training as a historian of science, is that the practice of science can be analysed using methods drawn from the humanities and social sciences (such as philosophy, anthropology and sociology). Following on from this, one can claim that the inscriptions of science (i.e. scientific writing) can be studied from a literary-critical perspective.

We must be careful not to end up with the asymmetrical and patronising suggestion that science is amenable to analysis by the humanities, such that the former discipline can be explained (or even explained away) by the latter. Thankfully, this is not too much of a danger. Over the past decade or so, there has been an increased interest in science, and science has been integrated to a considerable extent into circles that previously confined their discussions to the arts. For example, the British broadcaster Melvyn Bragg has prominently featured the sciences amongst the humanities in his respected radio shows *In Our Time* and *Start the Week*. Public intellectual culture has begun to respect the fact that science has a passionate, 'big-questions' side to it, and that a meaning-saturated approach to the world is not restricted to the arts and humanities, as has sometimes been arrogantly presumed. Thus science and literature are in constant dialogue, and science can help to illuminate the nature of literature, as well as vice versa.

Historicising literature and science

When the first drawings of things seen through microscopes appeared, natural philosophers had to learn how to read them. They had to learn how to judge whether any given image was likely to be accurate, and what kinds of things could be learned from it. The best – perhaps the only – way to do this was by learning to use microscopes themselves. They had to learn what kind of things would work as specimens, how to prepare them, how to light them and how to focus on the right element of the sample. They had to learn the knack of looking down the microscope with one eye while using the other to draw a picture of what was shown. Gradually, they learned that you can ask some questions of

microscopic images, but not others. For example, one usually cannot ask about the colours of the specimens, since often a staining process is necessary to make certain features visible – that is, artificial colouration.[6] Similarly, one cannot usually ask about how the specimen moves, since the preparation process often involves killing the sample. (Or if it did move, it would probably go out of focus.) Over time, a new way of drawing was agreed upon: one that used only lines, and not shading. This was intended to demarcate clearly between what was agreed to be present in the sample and what was only 'interpretation'.

The novel was a new literary technology that arose at about the same time as the microscope. Just as we take microscopic images for granted today, so we are also inclined to forget what a remarkable new phenomenon the novel was originally. These lengthy pieces of prose treated fairly ordinary situations, unlike the subject matter of epics or classical or traditional romances. They presented their personae as fully rounded characters, rather than as ciphers in a story. Readers got to know the protagonists of novels almost as though they were their friends or relations. By making use of journal or letter formats, novels overlapped with the literature of everyday life; they appeared to chronicle, or be a part of, the real world.

Just like natural philosophers with their microscopic images, so users of the novel had to learn what to do with this new form of inscription. Communities of readers (and their overlapping communities of writers) have together continued to develop ways of reading novels, agreeing between them what questions are interesting and valid to ask of them. So, for example, members of a book club might ask a psychological question: 'Why do you think this character did this?' as though the character had a full interior life. But they are less likely to ask 'How tall do you think this character is?' because his physical nature is not so important. Such readers might speculate about what happens after the end of the novel, as though its events really continued – especially if the novel's ending is ambiguous. But they are less likely to ponder what the characters did before the story began, or in their childhood. They might ask why the author chose to interweave two narratives, but they are extremely unlikely to ask why he or she decided to write in prose. More academic audiences are similarly engaged in an ongoing process of agreeing what questions are appropriate to ask of novels.

Science, like literature, has changed enormously in the time stretching from Aphra Behn to Ian McEwan. Its name in the time of John Donne, Jonathan Swift and Samuel Richardson ('natural philosophy') suggests how it took a broader approach to nature than the modern-day

discipline. Natural philosophy included not only the 'how' questions posed by modern science, but also the 'why' ones that are today excluded. It was not enough to ask the question 'how many planets are there in the solar system?' Natural philosophers would also wonder '*why* do we see that number?' Could it have something to do with the mathematical patterns of certain numbers? Or did it have to do with God's plan? Philosophy and theology were all included in natural philosophy. There was also much discussion about the best methods of finding things out (that is, epistemology). Today such speculation is left out of journal articles, but previously there was lively debate about questions like 'which is more reliable, the evidence of our eyes or the logic of our minds?' as we shall see in Chapter 1.

Natural philosophy included some subjects – such as alchemy and astrology – that do not seem like science from a modern perspective. Isaac Newton (1642–1727), although known as the discoverer of gravity and all the calculus equations that describe it, is an overused but nevertheless excellent example of the strangeness of natural philosophy. Simplistic histories suggest that before Newton exercised his 'genius', everyone was ignorant about why things fall to Earth and planets go round the Sun. Then, so the story goes, he explained the modern scientific solution and that was that. Rather fewer of these science textbook histories reveal that although Newton spent about four years on gravity, he spent *forty* years on alchemy – trying to turn lead into gold through secret and mystical processes. This historical fact doesn't fit into the image of a modern scientist, so it is often omitted (or else included as an amusing curiosity). However, such an activity is exactly the kind of thing one would expect from a natural philosopher. We might be tempted to discount Newton's alchemy on the grounds that it did not contribute directly to modern science in the way that his theory of gravity did. But this would ignore that fact that so far as Newton was concerned the two activities were complementary – different sides of the same coin. Both were about uncovering the secret and mystical patterns of the universe.

Looking at natural philosophical literature before about 1800, or maybe even 1850, we find that the distinction between scientific writing and other kinds of publication blurs considerably. Because philosophical and scientific approaches were mixed together, there was a single audience for natural philosophy and other kinds of literature. In Newton's day, the same person might collect books on the Greek myths, theology, types of rock and cosmology (how the universe works – that is, what Newton wrote). During the Enlightenment, the reading public

read science just as they read Locke, Rousseau and Richardson. Indeed, some scientific research was published in formats that would seem bizarre today; Charles Darwin's grandfather Erasmus wrote an epic poem on the latest discoveries of Charles Linnaeus, called *The Loves of the Plants* (1789). It was a racy account of botanical sexual organs, all wrapped in an extraordinary style for which the term 'flowery' was surely invented.

Ralph O'Connor (2007) argues forcefully for the unity of literature and science in the early to mid-nineteenth century, using geology as his case study. O'Connor simply asserts that science *was* literature at this time. He points out that the terms 'science' and 'literature' as we have them now were both consciously constructed to satisfy particular cultural identities (in the early and late nineteenth centuries respectively) and that it is therefore both unnecessary and unwise to project a 'relationship' between them back into the past. For O'Connor, the fault lines lay not between science and literature, but between various aspects of popular, genteel and specialist culture.

During the course of the nineteenth century, the reading public expanded to include a proportion of the working classes of the industrial revolution. The scientific diet of these readers was often laden with rather patronising moral lessons, produced by well-meaning philanthropists. Radical members of these classes, however, seized upon science and read it as an atheistic force which might liberate them from the church-based government and – ironically – the very kind of people who tried to preach to them through science. For the upper-middle classes, this was the era of the journal, the quarterly review and the magazine: publications to which all cultured readers subscribed. There was a common audience for scientific and other types of essay in the pages of the *Westminster Review* and the *Edinburgh Review*, amongst other titles. In the same magazine one would find a discussion on feminism, a review of George Eliot's latest novel and an account of natural selection. Knowledge was less specialised than it is today, and educated readers would respond to both the scientific and the literary elements of any text.

In 1833 the poet Samuel Taylor Coleridge prompted the Cambridge fellow William Whewell to coin the word 'scientist'. His neologism referred to a group of men who wanted a name to reflect the fact that they took their scientific interests seriously, analogous to serious artists. In adopting this name, they were also distinguishing themselves from the wider reading public who simply consumed science. Towards the very end of the nineteenth century, the term 'scientist' finally came

into widespread use, just as men of science were becoming fully professional. There was a set training to become a scientist, and a pay cheque to go with the job. This trend of professionalisation has continued to the present day, with science and scientists being ever more tightly designated. These days, not just anyone can call themselves a scientist. He or she will generally have a PhD and will work in a laboratory at a recognised university or industrial company. They will publish their research in one of a number of recognised journals which self-regulate their professionalism by having senior peers in the field review articles for their scientific quality before publication.

As may be surmised, the appearance of such journals constituted a significant change in the literary forms of science during the twentieth century. Researchers started up more and more specialist journals, publishing articles on ever-narrower fields that became harder and harder for the outsider to read. Watson and Crick's famous article about the structure of DNA, coming nearly a century after Darwin's *Origin*, was published in a specialist scientific journal which would hardly be read by anyone who didn't spend their working time inside a laboratory. Books had changed by then too: they rarely announced new research (like Darwin's had done) but rather popularised existing knowledge for a wider audience.

Thus it is not only the case that science and literature have changed through time; the relationship between them has also changed. This means that it is very important to give scientific novels a historicist reading, that is, to place ourselves in the shoes of the original readers. There is no point in judging a text by today's science; it is utterly immaterial whether the science was right or wrong by current standards. What matters is what it meant to people at the time. We have to ask how an original reader might have responded to the themes and metaphors of a text. What contemporary issues would it have made them think about? What thoughts would it have sparked off? To answer these questions we have to consider both text and context, asking questions that derive both from literary and historical study. By combining the complementary insights of literature and history we can attempt to situate each novel in its original community of readers, looking for interpretations that would have likely been held in common or, if they did not all agree, were considered worthy of discussion by them.

If you are primarily a humanities student, one of the main things you should therefore gain from these historicised readings is an understanding of different kinds of past science, in the fullest sense of what they meant to people at the time. However, there is much more to literature

and science than learning about science (just as there are other ways to learn about science than reading novels). Looking at the two together helps us to understand the process by which the credible knowledge of science is agreed. One of the perennial questions that people have asked about science is how they can be sure of its claims. How do we know if we can trust natural philosophers or scientists?[7] This is the most important question of this study, and it will be addressed through interwoven literary and historical strands. My chief claim, expanded in the remainder of this introduction, is that it is the *form* of novelistic literature that has the most to say about belief and disbelief or that constitutes a dialogue with the claims of science.

It is very often on the basis of form that we make our judgements concerning knowledge claims. We do not merely judge the contents of a claim but also the framing of its communication – the vehicle of the knowledge proposed. This is very obvious when we think about person-to-person communication. We continually make judgements about whether to believe someone depending on their accent, dress and appearance. The same is true of written communication: a person claiming to be well educated in their job application will not be trusted if their CV is misspelled; a prediction about the housing market will not be taken seriously if it is written in an estate agent's blurb. Often one of the main features of a novel is the way that it engages the reader to think about such issues of belief and disbelief. Sometimes a true story will be disguised by anonymity; sometimes a made-up tale is presented as fact. Characters and narrator must all be judged for their trustworthiness. When scientific ideas are part of a novel, this process of interrogating credibility that is implicit in the novel form extends to the science as well. The framing of a story is itself a way of understanding what its original community of readers thought about how all stories, including those of science, were told.

Using form to study literature and science

In recent years, scholars in literature and science have tended to take one of two approaches. The first is firmly rooted in literature and revolves around metaphors; one of its best-known exponents is Gillian Beer. For Beer, the sticky edges of metaphors – the connotations that come attached to them – are their key property. People who invent metaphors, she argues, cannot control them afterwards. Because of their connotations, metaphors are forever suggesting new connections, escaping from the context in which they were invented and forging

new links between the world and our ideas. This critical stance reflects a key insight from the sociology of scientific knowledge: that no fact is real (or real to us, which is all we can know) independent of its representation. It has produced some excellent studies chasing metaphors in and out of fiction and fact, showing how scientific and cultural perceptions have been reciprocally transformed. Some studies, particularly the ground-breaking books of Gillian Beer, Misia Landau and George Levine, have looked at entire plots as metaphors for evolution. They have found that these metaphors both reflected and informed the 'plots' ascribed to nature by scientists. However, in successfully closing the loop of influence – in showing how metaphor has actively stimulated science – these scholars have often been in a minority. Many other scholars of this ilk, despite their best intentions, present a one-way process by which literary writers reflect on the metaphors of science, and not vice versa.

Paul White's biography *Thomas Huxley* (2003) has challenged somewhat this school of literary criticism and its assumption (especially amongst nineteenth-century scholars) that science and literature draw on a single pool of metaphors. White emphasises the multiple platforms and arenas in which Huxley worked to construct himself as a 'man of science'. Rather than having science sharing a single audience with literature, White highlights arenas of intersection as various as education (basic and advanced), industry, learned societies, popular culture, politics, culture and economics. In each of these, he argues, Huxley laboured to define different aspects of what he, and by implication science, was all about. This undercuts the notion that science works with a set of metaphors that can be found in some unitary notion of 'culture'.

A second recent trend in science and literature is rooted in cultural history and is known as the 'history of the book'. This means going beyond an analysis of the text and considering instead each book as a real, material artefact that is edited, published, bought, sold, lent and reviewed. This 'cycle of communication' forces the literary critic to think about actual debates and negotiations about what a book meant in its day, taking into account all its contexts of production and consumption. Insights from the history of the book have corrected the worst excesses of narratology, which proclaimed the author dead. (Extreme narratology does not only ignore authors; it can even omit real, historical readers from its consideration, replacing them with the superior, ideal sort that exists in modern academia.) Authors are in fact very much alive to their contemporary readers, as historians of the book have found. Readers *do* speculate about authors and their intentions, in every register from the scholarly to the scurrilous. They gossip about them, write

to them, meet them. History of the book avoids the narratological sin of attributing intention to the author not by 'killing' the author but by placing him or her in a community of interacting voices of publishers and readers, thereby making authorial intention – if present – just one of a competing set of historical interpretations.

As a historian by training, I am compelled to look at these real processes of authorship and reading. However, as a lover of novels, I am also wary of the history of the book. If using it as one's sole methodology, one might forget that literature creates a whole world of imagination that is wonderful precisely because it is *not* part of the humdrum business of buying and selling. In pursuing the question of form, this book attempts to do justice to books in both respects: as imaginative realms in their own right, and as material entities in a real, historical world. In this book, it is my core thesis that a study of form offers a way to synthesise these two modes of study and to move beyond their limitations, combining an historical appreciation of metaphor with an understanding of the cultural processes by which books are written and read.

What might a focus on form look like? Within the novel, form is about the narrative framing of a story, whose conventions are broadly shared and understood by historically located readers. This narrative framing gives the critic a major clue as to how the story was supposed to work, and how the reader expected to interpret it – although of course either reader or writer could choose to subvert those expectations. The literary critic Michael Whitworth has made this point succinctly: 'While content is a matter of individual conscious choice, literary forms are shared and are often unconsciously adopted'.[8] In other words, literary form tends to have a certain historical permanence and consistency that makes it a methodologically reliable topic for study.

The literary critic Wolfgang Iser defined form very simply as 'a means of communication or as a negotiation of insight' (Iser, 1974, p. 57), and I share his conviction that form is the best Archimedean point for that tricky task of inferring a reader's reaction from the text itself. We can use form to prise out the reader's reactions – not the disembodied, ideal reader of narratology, but rather the real readers who play their parts in the cycle of communication (as editors, publishers, purchasers, borrowers and reviewers). As writers developed new forms in literature, so readers developed new ways of reading. Discussion was entailed – whether explicit or implicit – about how these books should be written and read. Through their reading and writing, answers to key questions were negotiated: '*What counts as a convincing read?*' and: '*If something is a convincing read, about what sort of thing is it convincing?*' In other words, what kinds

of truths can literature cause its readers to find? Such developments in new ways of reading were also rehearsals for how to read other issues of the day, notably those of science. Books were and are experimental spaces for figuring out how the truths of science may be read.[9]

Thus my approach is broadly narratological, but for reasons and from a perspective provided by history. Narratology takes as its elements the story and its vehicle – the narrative, its structure and its presentation. In so doing it echoes the historian of science's distinction between a fact (in literary terms, an author) and its embedding in an act of witnessing (a narrative). The key insight is the same in both disciplines: that the former (the fact, the author) does not determine the latter (the fact's credibility, the text's reading). In both cases a formal framework is necessary for interpretation and judgement; a story and a proposed fact will both be judged depending on their presentation.

This presentation is an incredibly complex affair, resulting from the multiple layerings of communication within a text – some simple narratological elements. First and most obvious, there are the characters of a story. Then there is a narrator, who may or may not be one of the characters. The point of view from which the narration occurs is often called the focalisation of the text, a term that distinguishes she or he who sees from the person whose voice we hear. Finally, there is the author him- or herself, who may or may not overtly intrude their presence into the text. The author may address the reader directly; their voice may be ventriloquised by that of the narrator or one or more characters, or it may emerge from a structural feature of the plot (such as a happy ending that affirms the actions of the characters). Alternatively, the author's voice may be hidden, or ironic. The reader too is offered a role within the text, although she or he may reject it. She or he may be the recipient of the author or narrator's direct remarks; she or he may be implicitly figured in the role of a protagonist (like the pilgrim in *The Pilgrim's Progress*). She or he may also be cast in the role of a narrator or protagonist's confidant, especially in the case of confessional or epistolary narratives.

Thus there are multiple possibilities for author and reader to be constructed through the text. By attending to, and mentally interacting with, these layers of the text, readers (and writers) can try out different framings to see what kind of truths emerge. In each case, there is a reciprocal relation between the type of truth that emerges and how the reader (or writer) him- or herself is shaped. Throughout this book, I shall ask to what kind of dialogues texts invite their readers, and what constructions of science, and relationships of the reader to science, might thereby emerge.

Within this analysis I am particularly interested in how different narrative techniques can produce 'doorways' in and out of the text, or between its various layers. These are, if you like, wormholes between the different universes inhabited by the reader: the universe of real life, of absorption in the story and all the possibilities in between, such as a real life that incorporates certain features of the imagined one. Doorways in a text are moments or ongoing structures where the reader is invited to consider the experience of going into and out of the text, or travelling between layers of the text. They encourage him or her to think about what assumptions they have brought from the world to the text, or what changes in perspective might be carried back out into the world once the book's covers have been shut. As such, doorways play an important role in relation to the claims of science.

One obvious textual doorway is offered by a first-person narrator telling their story in a self-conscious manner. The reader puts him- or herself in the narrator's shoes and weighs up his judgement of events. A first-person narrator with vicarious experience of the story also suggests a doorway. The reader is encouraged to construct their reading as a vicarious experience, simply at one more remove. A doubtful or unreliable narrator is another kind of doorway on truth. The reader is forced to interrogate the narrator and/or events, and to form a judgement on what level or type of truth lies within the text. If the narrator is false then something else must be the truth. Going onto more interesting examples, we can point to the epistolary construction of novels. In such novels, there are elements of the text that have an aura of reality about them. The layers of text engage in dialogue with one another, in which the reader's thoughts become yet one more element. Perhaps the most interesting of all are the doorways between stories that are themselves within stories. Sometimes a novel (Shelley's *Frankenstein* [1818], Mitchell's *Cloud Atlas* [2004]) can be completely constructed in a Russian-doll formation, or sometimes these mirroring devices are formally less ambitious, although equally important to the text. By seeing the relation of one story to another, the reader is encouraged to think of their own story as yet another mirror to the text. In the case of Emile Zola we will also see the attempt to close down or control doorways within the text by use of the omniscient third-person narrative.

Thus the form of novels, considered historically, provides a framework for inferring their original readings, in particular the negotiations about truth and authority that have remained crucial since the birth of modern science and of the novel. In subsequent chapters, proceeding from the seventeenth to the twenty-first centuries, we will identify

some simple formal features of selected novels (character, narrator, focalisation, authoriality and textual doorways). We shall ask what conversations about science these facilitate, and how they shape reader, writer and notions of truth.

In Chapter 1 we consider the transition to modern science that took place in the later seventeenth century and the literary implications of the natural philosophers' switch from textual to observational knowledge (empiricism). Jonathan Swift is presented as a writer disinclined to take his decreased status lying down; his novel *Gulliver's Travels* is a sustained attack on what he saw as the lunacy of the new knowledge. This chapter sets up the historical background and philosophical dimensions that underlie the book's subsequent discussions of narratology and truth, and ends by comparing highly favourable accounts of empiricism from the mid- to late twentieth century with those of Swift. The positive angle of these accounts, it is argued, was made possible only by having forgotten the history of the earlier period.

In Chapter 2 a Benthamite model of law is employed as a key to reading Regency novels. Veremy Bentham proposed a radically democratic method for courtroom hearings, whereby everyone should be permitted to bring witness. I argue that this model also underpinned the reading and writing of much epistolary fiction; the layers of the text allowed the reader to hear multiple perspectives and even to simulate participation in the dialogue concerning the novel's economy of virtue. As such, the Benthamite model was an alternative to contemporary, morally absolutist recommendations about keeping women away from dangerous books. It implicitly suggested an opening-up of science to all comers and a willingness to entertain all theories, no matter how radical, subject to the critique of evidence. *Frankenstein* is selected as the key novel for study because it was both epistolary in nature and presented for readers' judgement a case of enormous political significance.

In Chapter 3, texts from the early Victorian era are subjected to a reading derived from William Whewell's influential model of scientific method. This method was considerably less democratic; it was based on idealism, according to which a person had to have the correct idea in mind before she or he could weigh up the claims of scientific observation. When it came to the novel, this implied that readers were, after all, and *pace* Bentham, liable to be misled by books if they were not the right sort of person. Novels did not conform happily to this form, however. Even Thomas Carlyle, in writing a novel about idealism (a philosophy towards which he was sympathetic), ended up producing a text that was actually more amenable to a Benthamite reading. His

complex levels of irony (echoed in the United States by Edgar Allan Poe) were open to multiple readings, and very difficult – if not impossible – to close off as Whewell's method of reading nature demanded.

Realism was a form of literature that replaced the self-conscious, Benthamite interplay of narratives with an attempt at a single, authoritative perspective. Chapter 4 discusses the origin of this form in the political turbulence of mid-nineteenth-century continental Europe. A comparison of Zola's *Thérèse Raquin* and Goethe's *Elective Affinities* makes the point. Both dealt with same topic, the ineluctable force of nature, but gave it different formal treatments. Goethe's was in the old school of interleaving texts, while Zola pioneered the application of the scientific method which he so admired, calling his 'experimental novel' realist.

In his esteem for science, Zola also came to present the scientist as a heroic figure. This theme is developed further in Chapter 5, where I consider the form that realism took in Victorian Britain. I claim that Victorian realism was essentially moral rather than ontological, and examine its transition from a theological form in the nineteenth century to a rather more secular version of authoritarianism in the twentieth.

In Chapter 6 the subjectivist psychologies of the later nineteenth and early twentieth centuries provide a framework for the reading of novels from that period. This encompasses some of the literature that is generally designated as 'modernist', and I argue that modernism was a form that enabled readers and writers to rehearse their value-judgement of an era whose busy, often overwhelming experiences could not be fitted within the realisms of the nineteenth century. Extending subjectivity beyond the traditionally construed self was, for many writers, the only possible response to the latest developments in science and society.

Chapter 7 takes us up to the turn of the twenty-first century, and the novels of DeLillo and Franzen. Their works do not especially represent another evolutionary step forward in narrative form. If anything, they (or at least the novels discussed here) hark back to the morally realist, multiple subjectivity of George Eliot. What is noteworthy about them is that they change the perspective on scientific knowledge. All the way through Chapters 1–6, the implicit textual question has been about the production of scientific knowledge, and the proper response to its claims (trust or unbelief). DeLillo and Franzen, however, turn their moral focus to the consumers of science – the 'readers' of scientific knowledge – in a move that echoes the late twentieth-century shift to the reader's interpretative responsibility within literary criticism.

Literature and science in the present

As I have argued in this Introduction, literature does not merely *reflect* the process of negotiation whereby people decide whether or not to believe and value the claims of science. It also constitutes a part of that process of negotiation. This argument is easy to make for earlier periods (say, before 1850), in which 'literature' and 'science' were scarcely distinguishable genres. In more recent times, however, we must note that both science and literature have their own specialist spheres for negotiating the form of what counts as 'good' or 'true', at least within the past century or so. Scientists have professional bodies for arbitrating on what counts as acceptable knowledge. Only certain experimental methods are agreed to be reliable; only certain types of conclusions, couched in certain ways, are valid. For literary writers there is a more amorphous network of reviewers and prize committees to set the unspoken rules on what is valid and laudable. Nevertheless, the traffic between literature and science remains significant right up to the present day.

In the past, when science and the humanities were not so distinct, and when the cultural ascendancy of science was not a given, what was negotiated in one sphere as a valid way of knowing could hold good in the other. Or, perhaps, both science and literature could be seen as specific examples of the negotiation of general social values of credibility. (If we buy O'Connor's case, the argument is even stronger.) However, the situation is not so symmetrical in the present day. A scientist can read a novel but a novelist (or her average reader) is unlikely to be able to read a scientific paper. Therefore literature arguably has a *more* privileged role in the present, a more generally accessible space where the question of truth can be rehearsed.

Closely allied to the question of truth is the question of value. Novels also allow readers to work through the question of what things they really value. Truth is not just a question of factuality: in most cases it also possesses a weight of worth. When we speak of 'seeking the truth', we don't mean merely looking for verifiable facts, for these could be trivial. Instead the phrase implies something much more significant – that the quest will have moral substance. Novels, in raising moral questions and modelling their outworking in real life, are extremely good at helping readers to think these things through.

Just as it is in literature, so truth in science is also a broader thing than simple factuality. Before we decide whether or not to believe particular claims of science, we have to agree the general criteria for believing and valuing them. For example, in order for someone to say 'this is the gene

for such-and-such' we have to agree all sorts of other things first. We have to accept that there are things called genes that make our bodies and behaviours turn out the way they do. We have to accept that running liquids across gels and producing images that look like bar codes is a way of distinguishing these genes. We have to accept that people with a degree from a university are to be trusted in carrying out this process. We have to trust the credibility of the academic journal in which the claim is published, and that it polices the credibility of its submissions (something that will be done in part on a rhetorical basis). We have to trust that this is a good research project for our taxes to be spent on. Ultimately, we have to accept that this project answers questions that are useful and meaningful to our human existence. This whole, huge process of evaluating science is often invisible; it is above all a cultural process. Literature, as it engages in the processes of credibility – value and belief – engages in the very underpinning of science. Scientists (at least the ones I know) are not born, raised in and confined to laboratories. They are human beings who even, from time to time, read novels. Their aspirations in doing science, their aesthetic criteria for argument and even the questions they consider worthy of study are all shaped by their literary heritage as well as by other aspects of their education and culture.

Perhaps more importantly, patrons of science also read literature. Patrons of science are those who make research possible, mostly by coming up with the necessary funds. Patrons may also help in publicising science, thus enhancing its credibility and the dissemination of its claims. In former times, these patrons were rich aristocrats and rulers. They generally had no independent expertise in science, and so the grounds on which they decided what science was worthy of their support were overtly personal, human and subjective, depending on their own culture, ambitions and beliefs. Yet thanks to their finance and support, they exerted a powerful influence on the direction and achievements of science. They paid the scientific pipers and they often called the tunes. Today, the patrons of science are private industry and government, and ultimately, in the latter case, the electorate. CEOs and politicians decide which research programmes are worthy of support and which are not. Like patrons of former days, their judgements of science are based on subjective criteria; they are derived from many cultural sources, including literature.[10]

Dilemmas concerning trust in science are just as frequent and important as they ever were. We all believe in gravity now, and almost all of us believe in evolution. But do we want genetically modified foods? How can we best tackle climate change? Does the machine at CERN explain our

origins? Do we want the tax cost of an expedition to Mars? Even though science and literature are more specialist fields than they were in Darwin's day, and less likely to find readers equally at home in both spheres, novels can still open up these questions about the credibility and value of science. Indeed, literature reveals that belief in science depends on many things – credibility, trust, rhetoric, representation and human motivation – beyond the facts themselves. Thus literature is now, as much as it ever was, ground on which we can negotiate the criteria for judging science. Readers and writers of the novel today cannot help to negotiate the technical grounds for truth that hold in the laboratory or the specialist journal, but they can and do help negotiate what counts as truth in this bigger sense, including the kind of scientists who receive the greatest approbation and support for their work. Scientists, patrons of science, users of science and readers of novels, are overlapping communities; literature is a shared space where their common forms of truth and value are negotiated. The scientist E. O. Wilson put his finger on the phenomenon in an interview about why, at the age of 81, he decided to promulgate his lifelong scientific concerns by writing his first novel. 'While people respect non-fiction – they give you prizes for it', he explained, 'they *read* novels'.[11]

Today, science is everywhere; it is at the root of much of the global economy, and it is arguably our most culturally credible force – the last word in many debates. At its best science appeals to what is most deeply human about us; it is embedded in the cultural systems that define humanity. No wonder Ian McEwan, along with all the other writers discussed in this book, chose to turn his literary focus to science. As humanities scholars, who are also voters and consumers, we too need to get to grips with its appeal, its potential and its limitations. Our role as patrons of science *qua* taxpayers (a phenomenon of about the last sixty years) suggests an exciting new way of understanding the relationship between literature and science. Ultimately it is our values and our notions of truth that will direct science, and these values and notions are in large part thrashed out through our discussion of literature.

Literature is how we decide what matters to us, and what matters to us will determine nothing less than the future of science.

Further reading

Science and literature focusing on metaphor and plot

G. Beer (2000) *Darwin's Plots*, 2nd edition (Cambridge: Cambridge University Press). Classic account in which Beer outlines her theory of metaphors.

M. Landau (1991) *Narratives of Human Evolution* (New Haven, CT: Yale University Press). Argues that scientific accounts of human evolution are based on plots drawn from fairy tales.

G. Levine (1991) *Darwin and the Novelists: Patterns of Science in Victorian Fiction* (Chicago, IL: University of Chicago Press). Classic account.

Science and the history of the book

A. Johns (1998) *The Nature of the Book: Print and Knowledge in the Making* (Chicago; London: University of Chicago Press). Focuses on how publishers and readers construct scientific knowledge through the production and consumption of the written word.

M. Frasca-Spada and N. Jardine (eds.) (2000) *Books and the Sciences in History* (Cambridge: Cambridge University Press). Edited collection of essays with a similar methodological aim to Johns.

R. O'Connor (2007) *The Earth on Show* (Chicago, IL: University of Chicago Press). First chapter makes a strong argument for the unity of 'literature' and 'science' in the early nineteenth century.

P. White (2003) *Thomas Huxley: Making the 'Man of Science'* (Cambridge: Cambridge University Press). Argues that there were multiple cultural niches in which the definition of late nineteenth-century science was negotiated.

Accounts of form in the novel

M. Bal (1997) *Narratology: Introduction to the Theory of Narrative*, 2nd edn (Toronto: University of Toronto Press). Systematic theory of narrative.

G. L. Bruns (1975) 'The Formal Nature of Victorian Thinking', *PMLA,* 90, 904–18. Considers how the Victorians built up their constructions of meaning in literature and science by recourse to history.

M. Fludernik (2009) *An Introduction to Narratology* (Abingdon, Oxon.: Routledge). Overview of narrative theories.

G. Genette (1983) *Narrative Discourse: An Essay in Method*, translated by J. E. Lewin (Ithaca, NY: Cornell University Press). Systematic theory of narrative.

W. Iser (1974) *The Implied Reader: Patterns of Communication in Prose Fiction from Bunyan to Beckett* (Baltimore, MD: Johns Hopkins University Press). Theory of aesthetic response in which the reader learns to find and understand himself in the text.

M. Turner (1993) *Mechanism and the Novel: Science in the Narrative Process* (Cambridge: Cambridge University Press). Traces the historical relationship between mechanical philosophy and the form of novels.

Treating scientific writing as literature

C. Bazerman (1988) *Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science* (Madison, WI: University of Wisconsin Press). Account of what is now the knowledge-making genre *par excellence* in professional science.

J. Fahnestock (1986) 'Accommodating Science: The Rhetorical Life of Scientific Facts', *Written Communication*, 3, 275–96. Present-day focus: how the content of scientific claims is transformed as it moves from specialist to popular genres.

A. Gross (1990) *Rhetoric of Science* (Harvard, MA: Harvard University Press). Looks at how examples of scientific writing, old and new, work to persuade their audiences.

E. F. Keller (1996) *Refiguring Life: Metaphors of Twentieth Century Biology* (New York: Columbia University Press). How metaphors actively direct the course of scientists' research.

B. Latour and S. Woolgar (1979) *Laboratory Life: The Social Construction of Scientific Facts* (Princeton, NJ: Princeton University Press). Posits the idea that the main purpose of science is actually about producing writing, not theories.

S. Montgomery (1996) *The Scientific Voice* (New York: The Guildford Press). How scientific writing has changed through the ages.

G. Myers (1990) *Writing Biology: Texts in the Social Construction of Science* (Madison, WI: Wisconsin University Press). How texts work to make knowledge.

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Note: readers are advised to look through the suggestions for further reading at the end of relevant chapter(s) in order to find more on topics of interest.