'*It is written*': Representations of Determinism in Contemporary Popular Science Writing and Contemporary British Fiction

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Preface

This dissertation does not exceed the regulation length of 80,000 words, including footnotes, references and appendices but excluding the bibliography.

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration. Section 5.2 is partly based on work submitted in 2005 in fulfilment of the requirements of the MPhil degree.

The style conforms to that specified in the *MHRA Style Guide*, 2nd Edition (London, 2008).

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I save my deepest gratitude for my parents, for all their love and support; this is dedicated to them.

Contents

Abstract

This thesis examines the representation of two broad fields of science – the new physics (relativity and quantum mechanics) and the modern biological synthesis (genetics and evolutionary theory) – in two genres of writing – popular science writing and narrative fiction. Specifically, I consider the representations of determinism in recent works by a number of writers from both genres, concentrating on the literary techniques employed by popular science writers, and the scientific concepts incorporated by contemporary authors.

I argue that there is a tendency in popular science books on the new physics to emphasise the indeterminacy supposedly implied by those theories, and that a number of recurrent metaphors are integral to this representation. Similarly, I find that the novelists and playwrights drawing on ideas from this field of science (such as Amis, Stoppard, Frayn and McEwan) also emphasise this indeterminacy, but in addition that they use these concepts borrowed from physics to question the adequacy of science as a monistic epistemological system.

Popular science writing on genetics has a propensity, even while acknowledging the importance of environmental factors, to present a 'gene-centric' view, prioritising the effect of the genes in the development of an organism. Although these writers would (and do) deny the validity of genetic determinism, the emphasis on the role of genes and our evolutionary development gives support to the idea of the determining function of our biology. The metaphors and narratives used by popular science writers are again central to this representation. I go on to show how contemporary fiction writers (particularly McEwan and Byatt), in appropriating ideas from these scientific fields, critique this idea of biological determinism, and furthermore that they raise doubts about an exclusively scientific understanding of the world. I conclude this thesis by offering some thoughts on the epistemological role that literature might play in the face of this apparent dominance of a scientific conception of knowledge.

1 Introduction

"Science and fiction both begin with similar questions: What if? Why? How does it all work?" – Margaret Atwood [1]

A desire for explanation lies at the heart of both fictional narrative and scientific enquiry; tying fiction to science is the need not merely to describe but to explain. It also connects the many strands of scientific enterprise: "It is widely held [...] that all the sciences are unified at a deeper level in that natural processes are governed, at least in significant measure, by cause and effect".[2] As a result, the physical sciences are intimately connected to the idea of causality – to the process of taking one state and explaining what will follow from it, or taking a state and deriving its preceding causes. Causality is an essential underpinning of modern scientific rationalism and its "explanatory ambitions"; it is also the foundation on which fictional narratives are constructed.[3]

If narrative is the concatenation of causal connections, then the same extrapolation in science seems to imply the idea of causal determinism. Drawing on Carl Hoefer's discussion, determinism can be defined as follows: the world is deterministic if, given a specified 'way things are' at time *t*, the way things go afterwards is fixed as a matter of natural law.[4] If each new state of a given system is caused by the previous state of that system, then it would appear that since its beginning the whole universe has been a story which is in some sense already written. Determinism and narrative thus resemble each other: both are simply causality iterated. In this thesis I examine the representation of determinism in two broad fields of science – the new physics and the modern biological synthesis – as presented by two different genres of writing – popular science writing and contemporary narrative fiction.

That science has been an important influence on contemporary authors is hardly in question. One only has to read, say, Ian McEwan's introduction to his libretto *Or Shall We Die?* to realise

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1 'An interview with Margaret Atwood', <http://www.oryxandcrake.co.uk/interview.asp> [accessed 8 April 2010].

2 Norton, J.D., 'Causation as Folk Science', *Philosophers' Imprint*, 3:4 (2003), 1-22 <http://www.philosophersimprint.org/003004/> [accessed 12 May 2010], (p. 1).

3 Carl Hoefer, 'Causal Determinism', *The Stanford Encyclopedia of Philosophy*, Spring 2010 edn, ed. by Edward N. Zalta <http://plato.stanford.edu/archives/spr2010/entries/determinism-causal/> [accessed 10 May 2010], (Section 1, Introduction).

4 Hoefer, Preface.

the extent to which scientific advances have affected his writing. In so far as writers are concerned with describing the world and our perceptions of it and interactions with it, the alterations in our world-view brought about by, for example, the discoveries in physics at the beginning of the twentieth century are clearly momentous. As McEwan says, "Space, time, matter, energy, light, all came to be thought of in entirely new ways, and ultimately must affect the way we see the world and our place within it".[5] A.S. Byatt, whose writing has been influenced more by the biological than the physical sciences, makes a similar observation about the way in which paradigm shifts brought about by the sciences can affect novelists: "Recent discoveries about the great extent to which DNA patterns are shared by all creatures have perhaps changed writers' ideas of the natural world".[6]

Equally clear, though difficult to quantify, is the significant role that popular science writing has played in bringing science to the attention of authors. In the same introduction McEwan quotes from Gary Zukav's *The Dancing Wu Li Masters*, as well as appearing to refer to Fritjof Capra's *The Tao of Physics*; in her acknowledgements in *Cat's Eye* Margaret Atwood notes her debt to the "entrancing books" by Paul Davies, Carl Sagan, John Gribbin and Stephen W. Hawking and draws one of her epigraphs from *A Brief History of Time*; for *Oryx and Crake* Atwood provided a list of titles for 'Further Reading', almost all of which could be described as popular science books and has noted that "My recreational reading — books I read for fun, magazines I read in airplanes — is likely to be pop science of the Stephen Jay Gould or *Scientific American* type"; A.S. Byatt dedicates *A Whistling Woman* to the geneticist and popular science writer Steve Jones and in the acknowledgements thanks nearly a dozen other popular science writers, including Matt Ridley and Richard Dawkins; Tom Stoppard cites Richard Feynman's books as a source of much of the physics in *Hapgood*, even lifting a piece of explication for use in that play, and in *Arcadia* gives to one of his characters a close paraphrase of a line from Benoit Mandelbrot, almost certainly drawn from James Gleick's very successful account of chaos theory, *Chaos: Making a New Science*.[7] From these and other isolated examples it is reasonable to infer the wider and pervasive – and often unacknowledged – influence of popular science writing on contemporary writers.

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5 Ian McEwan, *Or Shall We Die?: Words for an oratorio set to music by Michael Berkeley* (London: Jonathan Cape, 1983), p. 15.

6 A.S. Byatt, *On Histories and Stories: Selected Essays* (London: Chatto & Windus, 2000), p. 80.

7 McEwan, *Or Shall We Die?*, pp. 17-18; Margaret Atwood, *Cat's Eye* (London: Virago, 1990), Acknowledgements; Margaret Atwood, 'Further Reading' <http://www.oryxandcrake.co.uk/furtherreading.asp> [accessed 10 April 2010]; Margaret Atwood, 'Perfect Storm: Writing Oryx and Crake' <http://www.oryxandcrake.co.uk/perfectstorm.asp> [accessed 10 April 2010]; A.S. Byatt, *A Whistling Woman* (London: Chatto & Windus, 2002), Acknowledgements, p. 422; Tom Stoppard, *Hapgood* (London: Faber, 1988), Tom Stoppard, *Arcadia* (London: Faber, 1993), p. 84.

Less frequently acknowledged by their authors, but equally apparent, is the importance of literary techniques in popular science books. While formal innovation is relatively scarce (making books like Douglas Hofstadter's *Gödel, Escher, Bach: An Eternal Golden Braid*[8] conspicuous exceptions), popular science books are manifestly literary, not to say novelistic.[9] All utilize metaphors liberally, and in many metaphor plays a prominent role (*The Selfish Gene*, *River Out of Eden*, *The Dancing Wu Li Masters*); similarly, all employ characterization to some degree, but some writers place characterization, normally of particular scientists, at the heart of their books (*Chaos*, *Wonderful Life*); most construct narratives, often around the 'discovery' of important theories or evidence within the relevant scientific field, but as with characterization, some books promote these narratives to a structural role (*Wonderful Life*, *The Double Helix*, *A Short History of Nearly Everything*); finally, literary epigraphs, references and quotations are commonplace, with some writers again making these literary aspects structurally integral to their books (*The Ancestor's Tale*, *Unweaving the Rainbow*, *The Red Queen*).[10]

Despite the acknowledgements of indebtedness by contemporary authors, or perhaps because of it, this thesis is not an influence study: I am not chiefly concerned with tracing the passage of ideas from popular science writing into the works of contemporary novelists and playwrights. Nor will I attempt to prove the less frequently pursued claim that popular science writers are influenced by the techniques, and possibly trends, of contemporary fiction. Rather, while acknowledging the complexities, this thesis begins with the assumption that there is a level of mutual transmission between the two discourses. There is much truth in Michael Whitworth's argument, referring to the assimilation of the implications of Einstein's theories of relativity into modernist writing, that, even if "we cannot assume the entire society would have been uniformly saturated with the new knowledge", there is still a 'field of force' of new ideas that allows us to presume the influence of these ideas on the authors of a period, even "in the absence of particular reports of reading or of conversations".[11] I will not, therefore, speculate about specific lines of influence (i.e. which popular science books an author may have read). Instead, I examine

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8 Douglas Hofstadter, *Gödel, Escher, Bach: An Eternal Golden Braid* (New York: Basic Books, 1979).

9 See below, p. 25 n. 67, for an alternative view of popular science as resembling autobiography.

10 Richard Dawkins, *The Selfish Gene*, 2nd edn (Oxford: Oxford University Press, 1989); Richard Dawkins, *River Out of Eden* (New York: Basic Books, 1995); Gary Zukav, *The Dancing Wu Li Masters* (London: Fontana, 1979); James Gleick, *Chaos: Making a New Science* (London: Vintage, 1998); Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (Harmondsworth: Penguin, 1991); James Watson, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* (London: Weidenfeld & Nicolson, 1968); Bill Bryson, *A Short History of Nearly Everything* (London: Black Swan Books, 2004); Richard Dawkins, *The Ancestor's Tale: A Pilgrimage to the Dawn of Evolution* (New York: Houghton Mifflin, 2004); Richard Dawkins, *Unweaving the Rainbow: Science, Delusion and the Appetite for Wonder* (Harmondsworth: Penguin, 1998); Matt Ridley, *The Red Queen: Sex and the Evolution of Human Nature* (Harmondsworth: Penguin, 1994).

11 Michael H. Whitworth, *Einstein's Wake: Relativity, Metaphor and Modernist Literature* (Oxford: Oxford University Press, 2001), p. 18.

the consequences – textual and epistemological – of the mutual transfer of ideas and techniques between the two genres of writing, concentrating on representations of determinism, and paying particular attention to the purpose to which writers in both genres have put these 'borrowings'.

Central to my argument is the contention that in both genres these appropriations are often strategic, serving the ends of implicit agendas. Popular science writing and literary fiction fall neatly into the two *blocs* of a 'two cultures' model, as representatives of the sciences and the literary arts. The phrase 'two cultures' comes, of course, from C.P. Snow's infamous 1959 Rede lecture, in which he argued that there was a growing cultural divide with "[l]iterary intellectuals at one pole – at the other scientists [...] Between the two a gulf of mutual incomprehension".[12] Although "many commentators now see his argument as outdated and redundant" or "reductive and simplistic", his model of culture has been extremely influential and contests between the two cultures *are* still conducted both through the media and in the academy.[13] As a result, we might expect to find that books from both genres contest the epistemological dominance of the opposing genre or discipline, or affirm the epistemological status of their own. In chapter 5 I show, for example, how a number of textual strategies in the popular science writing on genetics work to emphasise the importance of genes in the development and behaviour of an organism. This gene-centric perspective obviously promotes the epistemological status – the explanatory power – of genetics, at the expense of other forms of knowledge.

But while popular science texts do seem to utilise literary techniques to support their claims to epistemological priority, the relationship between the two genres is not neatly symmetrical. I have already mentioned that the borrowing of scientific ideas and images by novelists is more frequently acknowledged than the appropriation of literary techniques by popular science writers. Similarly, this kind of epistemological contestation is far greater on the part of the fiction writers, as they try to carve out an epistemological status for literature in the face of the apparently dominant sciences, widely considered the creators and verifiers of knowledge.

Two questions then raise themselves: firstly, do fiction writers draw on scientific ideas just to appropriate science's epistemological credibility for their own ideas – to, as Karen Barad puts it, "garner the authority of science for some theory or proposition that someone wanted to advance

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12 C.P. Snow, *The Two Cultures* (Cambridge: Cambridge University Press, 1993), p. 4. Here, as throughout this thesis, editorial ellipses are in square brackets – thus, [...] – to distinguish them from ellipses in the original text.

13 Elizabeth Leane, *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies* (Aldershot: Ashgate, 2007), p. 1; Whitworth, *Einstein's Wake*, p. 18.

anyway"?[14] Secondly, does this epistemological contestation represent little more than the rearguard action by a discipline relinquishing its hold on a right to define knowledge?

In answer to the first question, in chapters 4 and 6 of this thesis I show that literary texts normally incorporate scientific ideas as part of broader themes, that they are used where they support the wider aims of the text, and that these appropriations are often figurative or analogical; but that is not to say that their inclusion is in any way gratuitous. Rather, these authors can be frequently seen to be engaging with the 'borrowed' ideas epistemologically – not, obviously, by contesting or refuting the specifics of the theories in question, but by identifying the philosophical implications, and also, sometimes, questioning the "hasty epistemic confidence" of science.[15] I will offer some thoughts in the conclusion to this thesis towards the second question, proposing an epistemological role that literature might play by acting as a standing critique of science as the dominant epistemology.

Before turning to such questions, I present, in Chapter 2, a very brief overview of the history of popular science writing. I identify the middle of the nineteenth century as the best candidate for the moment of the emergence of the genre, while acknowledging that marking the moment in this way is essentially arbitrary, especially given a degree of confusion over the definition of popular science as a genre. I review the work done by those such as Shinn, Whitley and Hilgartner in the last thirty years to correct the dominant reductive view of popular science writing as the uni-directional translation – or worse, corruption – of high science for a lay audience, and recognise the importance in overturning this view. I conclude the chapter by clarifying my own use of terms such as 'popular science', 'public science' and 'pop science' for the purposes of this thesis.

The body of the thesis is then divided into four chapters which could be paired in either of two ways: by genre or by scientific discipline. They are ordered here so as to accentuate the connections between the representations of determinism across different genres of writing, but there are also many links that could be made between the depiction of the different sciences in the same genre of writing: for example, the implications of the depiction of biological determinism, on the one hand, and on the other, physical determinism in recent works of fiction; or, the features that are common to all popular science writing, regardless of the scientific discipline being explicated. Chapters 3 and 4 examine the representation of the new physics

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14 Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007), p. 18.

15 Bernard Harrison, *Inconvenient Fictions*: *Literature and the Limits of Theory* (New Haven: Yale University Press, 1991), p. 11.

(relativity and quantum mechanics), first in popular science writing (Ch. 3), and then in contemporary fiction (Ch. 4). Chapters 5 and 6 turn to the biological sciences. I consider first the representation in popular science writing of genetics (Ch. 5.1) and evolutionary theory (Ch. 5.2) and then examine the engagement with these same fields of science in recent fiction (Ch. 6).

These two very different areas of science – the new physics and the modern biological synthesis – have been chosen because the representations of them by popular science writers share a connection to the idea of determinism. But these were also the two areas that received the most widespread coverage in popular science books in the 1980s and 1990s. In particular, the popular science boom in the 1980s was built around physics with *A Brief History of Time* at the culmination. Then, in the build up to the publication of the HGP in 2000, evolution and genetics had their own boom. Patricia Waugh notes that the interest in science shown by novelists broadly follows the same pattern.[16]

The new physics can be interpreted as fatally undermining a fully deterministic understanding of the universe. Universal determinism is often associated with Pierre Simon Laplace, and his formulation from his 1814 *Essai Philosophique sur les Probabilités* is surely the most famous one:

> We ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it – an intelligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the motions of the greatest bodies of the universe and those of the lightest atom; for it nothing would be uncertain and the future, as the past, would be present to its eyes.[17]

The popular science books that I consider in chapter 3 tend to interpret the new physics as refuting the mechanistic vision of Laplacian determinism, presenting it as having indeterministic or anti-deterministic implications. In that chapter I will show how writers such as Gary Zukav, Fritjof Capra, Brian Greene and others explain the complex and sometimes counter-intuitive consequences of the new theories in ways that serve to support this emphasis on indeterminism. In the first half of chapter 5 I look at genetic determinism, and find that although none of the writers subscribe to a 'hard' form of genetic determinism and even while these texts explicitly acknowledge the role of environment, still the metaphors employed tend to support a gene-

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16 Patricia Waugh, 'Science and Fiction in the 1990s' in *British Fiction of the 1990s*, ed. by Nick Bentley (Abingdon: Routledge, 2005), pp. 57-77 (p. 57).

17 Pierre Simon, Marquis de Laplace, *A Philosophical Essay on Probabilities*, trans. by Frederick Wilson Truscott and Frederick Lincoln Emory from the sixth French edition (New York: John Wiley & Sons, 1902), p. 4.

centric stance – emphasising the determining effect of genes in the development of an organism over that of environmental factors. In the second part of chapter 5 I turn to evolutionary biology and find a related form of biological determinism in the presentation of evolution as having a teleological inevitability which culminates in our own evolutionary development. This is supported in part by narrative structures that equate the supposedly linear and cumulative progress towards scientific knowledge with a teleological interpretation of evolution.

This link between narrative and determinism that becomes apparent in representations of evolution in popular science writing perhaps indicates why these particular fields of science, and especially their implications for our ideas about physical and biological determinism, have caught the attention of fiction writers. In chapter 4 I show how novelists such as Thomas Pynchon, Martin Amis and Ian McEwan and the playwrights Tom Stoppard and Michael Frayn have utilised images and ideas from the new physics – and have also picked up on the apparent indeterminism implied by them, quite probably influenced by the emphasis on this angle by popular science writers. These borrowed concepts are often used in conjunction with a 'narrative indeterminacy' and a questioning of deterministic causality; but they also open up larger epistemological questions about the capacity of science to achieve complete knowledge of the world, and therefore the problems of scientific monism. The epigraph to this introduction, from an interview with Margaret Atwood, reveals that she sees fiction as tackling the same 'big' epistemological questions as science and points to the implicit belief that fiction can work towards answers to these questions. It is this idea, that science does not have a monopoly on answering the big questions, that can be seen in many of the novels that I will look at in chapters 4 and 6.

In chapter 6 I consider novelists' engagements with the biological sciences. Concentrating on Ian McEwan and A.S. Byatt, but also touching on David Mitchell, Margaret Atwood and Kazuo Ishiguro, I identify a loose pattern of resistance to the idea of a biological determinism founded either upon genetics or upon instincts resulting from our evolutionary development. McEwan's engagements with these fields are of particular interest, since many of his key protagonists are scientists and unashamedly rationalist in outlook, often openly disparaging towards literature; and yet his novels tend to enact a more nuanced critique than his characters, not easily shoehorned into a two cultures model.

These two chapters on fiction look predominantly, but not exclusively, at British novels of the last twenty years, though where relevant I also refer to novels by authors from America and Canada and to novels written before 1990. The most significant exception to this concentration is

in chapter four, which examines the representation of physics in recent fiction – here, the plays of Michael Frayn and Tom Stoppard are too significant to omit from the discussion, and hence are included as an important part of that chapter.

Whether literature can create or convey 'knowledge', or even be said to contain truth, is open to question. 'No-truth' theories of literature stretch back, of course, to Plato's opinion in Book X of *The Republic* that art and literature cannot teach anyone anything because "teaching requires something to teach, namely, knowledge, moral or otherwise; and knowledge, according to Plato, was something that neither literature nor art had to offer".[18] More recently, Lamarque and Olsen argue, in *Truth, Fiction and Literature: A Philosophical Perspective* ("surely the most comprehensive philosophy of literature in the analytic tradition to date"[19]), that literature's value does not lie in its capacity to contain truth, and that any truths it can contain are not new for the reader, but already understood by them.[20] Noel Carroll categorises Lamarque and Olsen's position as a 'banality argument', one of three categories of no-truth theories that he identifies: 'no-evidence' arguments, 'no-argument' arguments, and 'banality' arguments.

No-evidence arguments note that although literature can contend views that are themselves true, it cannot confirm the truth of these views itself – few works of art or literature evince evidence for their 'claims'. No-argument theories of literature state that even if works contain truths, neither the work itself nor the critical discourse around them argue for these truths: these truths just do not seem to be an important feature of works of literature or art. Finally, the banality argument may be summed up by the scathing comment of Richard L. Purtill that the truths that fiction illustrates "seem so platitudinous and threadbare as to raise serious questions about the importance of artistic truth".[21] Critics have put forward pro-truth arguments, but in general they appear partial or unconvincing.[22] What then, if any, is literature's epistemological value?

Margaret Atwood's comment on the similarities between science and fiction that begins this introduction also indicates, perhaps inadvertently, one important way in which literature differs from science. Literature's capacity to ask 'what if?', to address the counter-factual and speculative, has been highlighted by proponents of pro-truth theories as one way in which literature can play

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18 Noel Carroll, 'The Wheel of Virtue: Art, Literature and Moral Knowledge', *The Journal of Aesthetics and Art Criticism*, 60 (2002), 3-26 (p. 3).

19 Ibid.

20 Peter Lamarque and Stein Haugom Olsen, *Truth, Fiction, and Literature: A Philosophical Perspective* (Oxford: Clarendon, 1994).

21 Quoted in Carroll, p. 4.

22 Carroll; M. W. Rowe, 'Lamarque and Olsen on Literature and Truth', *The Philosophical Quarterly*, 47 (1997), 322-41; Peter Mew, 'Facts in Fiction', *The Journal of Aesthetics and Art Criticism*, 31 (1973), 329-37.

an epistemological role – by, for example acting as thought-experiments, or generating hypotheses.[23] These seem like insignificant concessions, giving to literature functions that are fulfilled sufficiently already by other disciplines outside literature. These pro-truth arguments almost ignore the 'literariness' of literary works and, more importantly, subscribe to precisely the criteria for knowledge creation that are established by science, thus affirming them. I will return to this question in my conclusion, but it is worth noting now that the engagements with science in the literary works that I examine in this thesis might point us towards a possible response to the question above and a route out of this bind. As they appropriate scientific ideas for their novels and plays these authors also consider them epistemologically, and their attention reveals the limitations of scientific knowledge. Literature can act as a reminder of the boundaries of scientific knowledge, and of the dangers of a monistic scientific epistemology. As Bernard Harrison puts it, "the peculiar value of literature in a culture such as ours, the thing which really does make it essential to a civilised society, is its power to act as a standing rebuke and irritant to the dominant paradigm of knowledge".[24]

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23 Carroll, pp. 7-11 et passim; Mew, pp. 329-37.

24 Harrison, p. 4.

2 A Historical and Theoretical Contextualisation of Popular Science Writing

Any study of popular science writing faces an immediate problem of definition. Quite what is considered to constitute popular science as a genre varies depending on the interest of the researcher and the nature of their approach to popular science writing; likewise there is only limited agreement concerning the common characteristics of popular science writing. Additionally, there is no stable vocabulary for discussing popular science – terms such as 'popularization', 'pop science', 'popular science', 'public science', 'public understanding of science' or 'expository science' are used in ways that overlap with and contradict their use by other researchers.[1] Jon Turney has noted that we "lack an effective critical vocabulary for discussing popular science books", and while Leane is perhaps correct to respond that "one could equally argue that we have a superfluity of vocabularies" the problem remains: there is no consensus concerning the terminology of the study of popular science.[2] The purpose of this section is therefore to outline my own conception of the field of popular science and to attempt to identify a set of criteria useful for delimiting the genre of popular science writing; finally I will clarify my own use of key terms.

As a point of departure for this theoretical background it will be useful to briefly place popular science within its historical context. This thesis is not a historical analysis of popular science writing, so this will necessarily be an overview of a complex area that has been extensively studied by other scholars.

2.1 A Brief History of Popular Science

It is a slightly thankless task attempting to identify the moment of the emergence of popular science as a genre. Gregory and Miller put forward the possible view that popular science writing could be deemed to predate scholarly communication of science – citing Herodotus, Lucretius,

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1 Peter Broks, *Understanding Popular Science* (Maidenhead: Open University Press, 2006), p. 1.

2 Jon Turney, 'More Than Story-Telling: Reflecting on Popular Science' in *Science Communication in Theory and Practice,* ed. by Susan M. Stocklmayer, Michael M. Gore and Chris Bryant (Dordrecht: Kluwer Academic Publishers, 2001), pp. 47-62 (p. 47); Leane, p. 22.

Copernicus and Galileo – and it is a not illogical conclusion.[3] However, it is sensible to begin with the assumption that 'popular science', as something sufficiently distinct from 'science' as to form its own genre, could only really come into being as science became more professionalised – though I will discuss the criticisms of this view later. This places the emergence of the popular science genre firmly in the nineteenth century – after all, if 'popular science' presupposes 'science' then 'science', as the title of an academic discipline, only replaces 'natural history' during the nineteenth century; the term 'scientist' is only coined by Whewell in the 1830s.[4] Identifying, more precisely, a decade, or even half-century, in which popular science can be said to emerge is, however, extremely difficult. As Bernadette Bensaude-Vincent concludes in her examination of popular science in the twentieth century "there is nothing like a linear process of development of the popularization of science [...] it is a complex and multidimensional phenomenon which has periods of expansion and relative decline", and this is as true before the twentieth century as within it.[5] Nonetheless, in the middle period of the nineteenth century, between 1820 and 1870, there was a significant growth of popular science publishing – particularly in periodical form: "Popular science periodicals began to appear in the 1820s […and their] production peaked in the 1860s", a decade that Ruth Barton refers to as the "high point in popular science periodical publishing in nineteenth-century England".[6] Similarly, Sheets-Pyenson tells us that it was in the 1850s and 1860s that a group of *vulgarisateurs* began to form in France to disseminate 'high science'.[7]

John C. Burnham identifies a similar 'boom' in the United States, albeit during the following decade: "popularization of science reached an unusual peak of intensity in the early part of that decade [the 1870s]".[8] This slight delay is fairly explicable given that "Residents of the New World had habitually, if reluctantly, looked to the Old World for civilization and learning", and, more directly, that much of the popular science material in the US was actually "reprinted (usually pirated) English books" and that "American magazine editors for decades borrowed openly from

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3 Jane Gregory and Steve Miller, *Science in Public: Communication, Culture and Credibility* (Cambridge, MA: Basic Books, 2000), p. 19.

4 David M. Knight, *Natural Science Books in English, 1600-1900* (London: Batsford, 1972), p. 1; David M. Knight 'Scientists and their Publics: Popularization of Science in the Nineteenth Century' in *The Cambridge History of Science, Volume 5: The Modern Physical and Mathematical Sciences*, ed. by Mary Jo Nye (Cambridge: Cambridge University Press, 2003), pp. 72-90 (p. 73).

5 Bernadette Bensaude-Vincent, 'In the Name of Science', *Science in the Twentieth Century,* ed. by John Krige and Dominique Pestre (Amsterdam: Harwood Academic Publishers, 1997), pp. 319-38 (p. 336).

6 Susan Sheets-Pyenson, 'Popular Science Periodicals in Paris and London: The Emergence of a Low Scientific Culture, 1820-1875', *Annals of Science*, 42 (1985), 549-72 (p. 551); Ruth Barton, 'Just Before *Nature*: The Purposes of Science and the Purposes of Popularization in some English Popular Science Journals of the 1860s', *Annals of Science*, 55 (1998), 1-33 (p. 2).

7 Sheets-Pyenson, p. 556.

8 John C. Burnham, *How Superstition Won and Science Lost: Popularizing Science and Health in the United States* (New Brunswick: Rutgers University Press, 1987), p. 159.

English magazines".[9] But already by the 1840s Americans had "started using the term 'popularize' frequently".[10] Even before this, writers were well aware of the rise of popular science: writing in 1830 one reviewer notes that "[i]t is indeed one of the peculiar and great undertakings of the age, to communicate scientific knowledge to the whole intelligent portion of the mass of society […] *Diffusion* is the watch-word of the age".[11] 'Diffusion' implies a slightly different process to popularization, one in which the scientific knowledge remains unchanged as it is disseminated. Whether this is possible even in scholarly scientific texts and communications is open to question, but it would certainly seem to place diffusion in a separate category to popular science writing.[12] Nonetheless, Burnham notes that "diffusion of scientific knowledge in the United States turned into popularization early in the nineteenth century" and identifies a "significant expansion of popularization and the rise of the term in the 1840s".[13]

There are obvious social and historical reasons for this 'boom', that are not peculiar to science publishing, and are those which gave rise to increased publication in general; indeed, Sheets-Pyenson observes that the rise of science periodical publication from the 1820s to a peak in 1860s "follow[s] the contours of general periodical publication".[14] These general factors were the increasing literacy of the masses on the one hand, which created a market, and changes in printing technology which allowed for cheaper production. Moreover, Sheets-Pyenson notes other social and technological conditions that facilitated the success of these "new forms of popular literature" – such as less restrictive legislation and lower taxation on advertisements and paper, and the use of new transportation facilities like railways for distribution – as well as cultural changes, in particular a "more literate and leisured public" and the notion that "[r]eading, a purely intellectual pursuit, was praised for producing 'habits of reflexion' particularly 'favourable to orderly conduct'".[15] Having recognised these general conditions Ruth Barton notes that "there were also changes in the form and content of popular science journals which suggest changes in the status and nature of the scientific community".[16] Specifically she highlights a shift, in the years before the 1860s, from an emphasis on the utility of science, mechanical processes,

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9 Burnham, p. 129.
10 Burnham, p. 32.
11 'Diffusion of Knowledge', *North American Review*, 30 (April 1830), 293-312 (p. 295, p. 297). Quoted in Burnham, p. 32.
12 R.G. Dolby, 'The Transmission of Science', *History of Science*, 15 (1977), 1-43.
13 Burnham, p. 33.
14 Sheets-Pyenson, p. 551.
15 Sheets-Pyenson, p. 549, p. 550. For the changing economic and social conditions of periodical publication see also W.H. Brock, 'The Development of Commercial Science Journals in Victorian Britain' in *Development of Science Publishing in Europe*, ed. by A.J. Meadows (Amsterdam: Elsevier Science Publishers, 1980), pp. 95-122.
16 Barton, p. 3.

amateur scientists and a sometimes critical attitude towards theory, to an emphasis on professional science and theory, and a "denigratory [attitude towards] interest in mere utility":

> From the 1820s to the 1850s popular journals had espoused an experiential, inductivist science to which all their readers could contribute…[this] began to disappear in the new journals of the 1860s when popularizers sought not participation from amateurs but support for professionals.[17]

These two forms of popular science periodical writing in the nineteenth century are described by Sheets-Pyenson as 'low science' and 'popular science' respectively. Those periodicals of the early- to mid-nineteenth century, which aimed not to 'translate' or disseminate scientific knowledge or discoveries, but rather to encourage and support amateur science Sheets-Pyenson terms 'low science' as they "sometimes sought to establish their own canons of scientific investigation, criticism, and explanation", not quite in opposition to, but as separate from, 'high' science. Popular science, then, is better seen as "a subset of 'low science'; specifically it is that kind of 'low science' that attempts to make 'high' scientific discourse intelligible to the non-scientists". By contrast 'low science' sometimes "vigorously opposed the 'high' scientific establishment".[18]

This is a useful distinction because it draws attention to the fact that an important element in popular science (or popularized science) is the idea of it acting as a 'translation' from the discourse of 'high' science to that of the 'general public'. This view of popular science as a translation has been criticised as part of the 'dominant view' of popular science (to use Hilgartner's phrase) by scholars who have rightly noted that translation is often equated with simplification or corruption. I will examine these arguments in more detail towards the end of this chapter. While I follow these critiques and accept that it is important to adjust our conception of how popular science mediates between these two discourses, and how the two communities are constituted – specifically, to accept that the mediation is not uni-directional and to resist reductive approaches to the genre – I believe that its mediatory role is significant in demarcating the genre.

Burnham is in no doubt about this mediatory role, nor indeed as to the relationship between the rise of professional scientists and the 'boom' in popular science writing in the latter half of the nineteenth century:

> The significant expansion of popularization and rise of the term in the 1840s reflected the appearance in the United States of professional scientists, people

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17 Ibid.

18 Sheets-Pyenson, p. 551.

> whose knowledge and activities now clearly differentiated the group from their fellow citizens. People within the scientist group tended to speak the same language – at least enough to understand each other. Observers therefore spoke then and have spoken since of the need to simplify and interpret or translate for the masses outside the expert group.[19]

My analysis of the rise of popular science in the nineteenth century does not preclude the fact that there is a much longer history of the exposition of ideas for a non-specialist audience within natural history and natural philosophy, ideas that we would now categorise as science. Isaac Asimov, in an article for *Nature* in 1983 called simply 'Popularizing Science', suggests that Bernard le Bovier de Fontenelle, author of *Entretien sur la pluralité des mondes* (1686), "was perhaps the first person to make a reputation in science on the basis of his popular science writing alone".[20] Similarly, G.S. Rousseau, in his essay 'Science Books and their Readers in the Eighteenth Century', uses the phrases 'popular science' and 'popularization' repeatedly to refer to books published in the eighteenth century: "the dissemination of natural philosophy after 1710 or 1720 caused an unprecedented consumer-interest in popular science books, a consumption that continued into the early nineteenth century".[21]

However, even though we may retrospectively construct a lineage of popular science writing from examples from the eighteenth century and earlier, there are a number of reasons why I choose to see the middle of the nineteenth century as the moment of the emergence of popular science. To return to Asimov's article, it is conspicuous, despite his claim for Fontenelle, that the other popularizers that he goes on to mention are all writing in the nineteenth and twentieth centuries: "there have been science popularizers ever since, including some important scientists – from Davy to Faraday, through Tyndall, Jeans and Eddington, to our contemporaries, Sagan and Gould".[22] The nineteenth century sees a qualitative change, and there are some general reasons for this. Firstly it is difficult to draw a line between popular science and original expositions of science in the eighteenth century. This continues into the nineteenth century, as Knight observes, but as the century progresses original science is more rarely written in a form intended for the general reading public.[23] So that by the beginning of the twentieth century, as Gregory and Miller observe, the "great scientist-popularizers of the 19th century (Charles Darwin, for example), who would write their new ideas in books accessible to a wide range of people, were replaced by the

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19 Burnham, pp. 33-4.
20 Quoted in Leane, p. 20.
21 G.S. Rousseau, 'Science Books and their Readers in the Eighteenth Century', in *Books and their Readers in Eighteenth-Century England*, ed. by Isabel Rivers (Leicester: Leicester University Press, 1982), pp. 197-255 (p. 211).
22 Quoted in Leane, p. 20.
23 Knight, *Natural Science Books*, p. 190.

popular scientists of the early 20th century (such as the astronomer Arthur Eddington), who would publish a journal paper and a popular book aimed at different, separate readerships".[24]

This reveals, then, another sub-division of popular science writing, since many science books written in non-technical language in the nineteenth century, such as Lyell's *Principles of Geology* or the *Origin*, were also the original description of theories or scientific evidence, rather than the popularization of science that had been published elsewhere, in journals or as monographs. I do not wish to present popularization as *merely* the collation and dissemination of established ideas, and I will show below that many popular science books that are exemplars of the recent form of the genre exhibit a range of levels of speculativeness and that they are still sometimes used to propose new scientific theories rather than explicate old ones; nonetheless, popular science writing in recent decades has tended towards the explication of scientific ideas already published in other scholarly forms, less often the case in eighteenth- and nineteenth-century science writing.

A second major difference between popular science in the mid- to late-nineteenth century and that which had gone before has already been touched upon: the question of audience. It seems fair to demand that a popular science book should reach, or at least intend or expect to reach, a fairly large audience from a range of backgrounds – that it should be aimed at a 'general readership'. For much of the period before the middle of the nineteenth century science books were inaccessible to the general public. Two details from G.S. Rousseau's essay reveal the narrowness of the potential audience for science books in the eighteenth century: on the subject of the rise of book clubs he says of the members that they "demanded printed science books and could now afford one or two"; in a footnote apparently supporting the "extent the new literate public was buying these books" Rousseau admits that "these books averaged £1 1s. so the common man could not afford them, but aristocrats, libraries, colleges and other institutions bought them".[25] Likewise Bensaude-Vincent describes the eighteenth-century public of science as "enlightened 'amateurs' who attended public lectures of chemistry and electricity and occasionally cultivated science as a leisure activity in their elegant 'cabinets'" – hardly a 'general public' then. It was not until the nineteenth century that, for some of the reasons already discussed, "a mass consumption of science developed".[26]

Finally, it might be admitted that there are pre-nineteenth-century works which do conform sufficiently to the criteria that I deem to describe the popular science genre (a set of criteria I will

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24 Gregory and Miller, p. 26.
25 Rousseau, p. 208, p. 247 n. 76.
26 Bensaude-Vincent, p. 320.

propose towards the end of this chapter) as to be called popular science. In other words, just as there are pre-eighteenth-century antecedents to the novel form that predate the rise of that genre, so these works of popular science are exceptions that foreshadow the nineteenth-century emergence of the popular science genre.

* * * *

So far I have argued that the genre that we know as popular science can be traced back to a divergence from a different category of science – academic science, or 'high' science. Bernadette Bensaude-Vincent is, however, resistant to this idea that popular science develops as a "kind of side-effect of a universal process of professionalization".[27] Historians of science, she says, are "inclined to consider the emergence of the popularization of science as a result of the specialization of science. Since scientific knowledge is increasingly specialized, complex and esoteric, it is assumed that mediations are required in order to bridge the gulf between a small elite of learned scientists and the mass of other citizens".[28] In her implied rejection of the idea of the 'gulf', Bensaude-Vincent is clearly drawing on the critiques of the 'dominant view' of popular science by Hilgartner and Whitley, critiques examined in more detail below; in brief, however, these studies question the idea of popular science as a uni-directional 'translation' of 'high science' for a lay readership.[29] Bensaude-Vincent seems to be arguing that just as popular science should not be seen as mediating across the gulf from elite scientists to lay readers, so its emergence should not be linked to the increasing specialization and professionalization of science in the nineteenth century.

There is, I believe, a slippage in this argument, primarily but not exclusively in the conflation of 'specialization' and 'professionalization'. This distinction is important: Bensaude-Vincent criticises the view that specialization leads to the growth of popular science because it suggests a hierarchy of knowledge; in other words, that as scientists become more specialised the science becomes more complex and popularizers are required to 'explain' this complex science to the general public. This is a model that clearly lies within the dominant view of popularisation reinforcing the superiority of scientific knowledge. However, to associate the rise of popular science with increased 'professionalization' is subtly different: this change in the scientific

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27 Bensaude-Vincent, p. 319.

28 Ibid.

29 Stephen Hilgartner, 'The Dominant View of Popularization: Conceptual Problems, Political Uses', *Social Studies of Science*, 20 (1990), 519-39; Richard Whitley, 'Knowledge Producers and Knowledge Acquirers: Popularisation as a Relation Between Scientific Fields and Their Publics', in *Expository Science: Forms and Functions of Popularisation*, ed. by Terry Shinn and Richard Whitley, *Sociology of the Sciences Yearbook 9* (Dordrecht: D. Reidel, 1985), 3-28.

disciplines created a new audience (or a much larger audience) of other professional scientists within one's field, at which technical scientific writing could now be aimed. As Knight puts it, before the nineteenth century "the number of active men of science in the country was small, and the number of professionals in the strict sense of being paid as scientists was very small indeed. Their books, and to some extent their papers too, had to be written with the inexpert reader in mind".[30] This changed, however, in the nineteenth century, and particularly in the second half of the nineteenth century, when "the number of scientists increased and scientific books and articles were, as a rule, directed at professionals".[31] Bensaude-Vincent is keen to distance herself from other historians of science whose approach sees "the emergence of science popularization as a necessary consequence of the 'advancement of science'".[32] But I suggest that the increased technicality of non-popular works (and hence the need for popular science writing) should not be seen as consequence of the advancement of science, but instead as a result of a shift in the intended audience of scientific works. In other words, we need not presume that science itself moved away from the public in terms of technicality (although this may also be true) in order to explain the rise in popular science, but rather observe that scientists, with a new audience of other professional scientists, were no longer writing for a general, if educated, readership. This professionalization meant that the "popularizer, and the text-book author, interpreter of the work of others, became increasingly necessary".[33]

While we should not return to the reductionist 'canonical' view of popular science,[34] it is important to recognise the mediatory role that popular science does play between two discourses. Hilgartner's argument that "'popularization' is a matter of degree" is convincing; but this does not mean that we should abandon all distinction between 'real science' and 'popularized science', nor does Hilgartner suggest we should: "The boundary between real science and popularized science can be drawn at various points depending on what criteria one adopts".[35] In other words, drawing a line between the two discourses is often arbitrary; but in order for popular science to represent a useful category we must still draw this line and distinguish popular science from real science.

To return, then, to the historical emergence of popular science in the nineteenth century, we can see that it is only with the creation and development of a discourse of 'real science' that popular

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30 Knight, *Natural Science Books,* p. 2.
31 Ibid.
32 Bensaude-Vincent, p. 336.
33 Knight, *Natural Science Books*, p. 2.
34 Reiner Grundmann and Jean-Pierre Cavaillé, 'Simplicity in Science and its Publics', *Science as Culture*, 9:3 (2000), 353-89 (p. 353 et passim).
35 Hilgartner, p. 328.

science can be understood to exist; quite when the two are deemed to part is clearly an arbitrary decision. To put it another way, popular science only branches off from science because science itself is moving in the opposite direction, away from popular science. Although I do not wish to see popular science as discontinuous with, unconnected to, or in opposition to, 'high science', and although popular science does have a discursive role to play in the formation of scientific knowledge, one of its primary functions is nonetheless to mediate between the discourse of professional science conducted in journals, at conferences and in laboratories and the discourse of the public image of science, and science in popular culture.

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Following the 'boom' period in the 1860s and 1870s there was an "unexpected decline of popular science literature [...] at the turn of the century".[36] Bensaude-Vincent attributes this dip in 'consumption' of popular science to a downturn in public confidence in science to provide solutions to problems, and a declining interest in the repeated celebration of progress.[37] The First World War, too, affected the public image of scientists: initially positively, as scientists were seen as mobilizing in support of the war effort; and then in the aftermath, negatively, as the use of chemical weapons tarnished the image of scientific endeavour. Following the war there was an attempt to reinstate the idea of the purity and nobility of science, and this was embodied, at least in the media and in popular science, in the figures of Einstein and Marie Curie. This emphasis on the individual brilliance of scientists was mirrored in the Nobel Prizes, created in 1901, but steadily gaining public exposure in the 1920s. The inter-war years saw another peak in popular science and it was during this period that "science popularization was established as a public institution in many countries".[38]

The 1920s and 1930s saw the rise of the 'new' physics, following Eddington's 'proof' of Einstein's General Theory of Relativity in 1919 through observations of the solar eclipse. Elizabeth Leane notes that the popularity and visibility of the new physics books prefigures the boom that was so widely noted in the last decades of the twentieth century: "The 1920s and 1930s saw a boom in popular physics books in both Britain and the United States, a publishing phenomenon which, like the late twentieth-century boom, was clearly identified by publishers and popularizers of the time".[39] Like the later 'Hawking Phenomenon', historians of popular science

36 Bensaude-Vincent, p. 321.
37 Ibid.
38 Bensaude-Vincent, p. 323.
39 Leane, p. 42; see also Michael H. Whitworth, 'The Clothbound Universe: Popular Physics Books, 1919-1939', *Publishing History*, 40 (1996), 53-82 (pp. 53-7), for evidence that contemporary observers

have sought to understand the factors behind this surge in interest in popular science; and, I contend, like the later theoretical physicist, Einstein's appeal has something to do with his own persona, but also much to do, paradoxically, with the incomprehensibility of his theories. It is widely joked that Hawking's *A Brief History of Time* is the bestseller that nobody has read, and Hawking's biographer Michael White records that "it has been estimated that only 1% of buyers actually read the book";[40] similarly, the impenetrability of Relativity, or more precisely the perception of its impenetrability, is perfectly epitomised by the, probably apocryphal, story that when asked if it was true that only three people understood relativity, Eddington replied "Oh, who's the third?".

After the Second World War there was, as Peter Bowler describes it, an "ignorance of science and a suspicion of what it might produce".[41] It is tempting to assume that public attitudes towards nuclear weapons were central to this distrust, and certainly there is evidence to support this. Peter Broks draws on Mass Observation documents that reveal that "in most cases the initial reaction [to the use of the atomic bomb in August 1945] was one of horror", and also that "when asked to think of science 'most people ... think of the bomb'".[42] Nonetheless he also cautions that "we must be careful of adopting such easy formulations" since anti-science sentiment and disillusionment had been growing since the early decades of the century.[43] Besides, post-war reactions to science were "deeply contradictory".[44] For example, he notes that, despite the suspicion of science, after the war "the public seems to have had a genuine thirst for knowledge", one that led to a "post-war bonanza" of popular science and an "outpouring of scientific information".[45] In the decades after the Second World War "popular science had never been so popular", with the broadcasting of popular science television programmes such as *Zoo Quest* (1954), *The Sky at Night* (1957-), *Tomorrow's World* (1965-2002), *Horizon* (1964-), *The Ascent of Man* (1973) and Carl Sagan's *Cosmos* which was seen by an estimated 140 million people in three years.[46]

By the 1980s, then, "there was talk of a popular science 'boom'".[47] In this thesis I will look at popular science books published during this 'boom', which "began rumbling in the late 1970s

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noted the boom in popular science writing.

40 Quoted in Leane, p. 49.

41 Peter J. Bowler, *Science for All: The Popularization of Science in Early Twentieth-Century Britain* (Chicago: University of Chicago Press, 2009), p. 265.

42 Broks, pp. 75-6.

43 Broks, p. 73, pp. 76-77.

44 Broks, p. 73.

45 Broks, p. 73; Gregory and Miller, p. 37.

46 Bowler, pp. 271-2; Broks, pp. 88-9; Gregory and Miller, pp. 42-45.

47 Broks, p. 88, p. 89.

and reached its peak in the 1990s".[48] Broks identifies the same "cultural shift beginning around the late 1970s and early 1980s" and cites the bookshop Waterstone's own *Guide to Popular Science Books* (2000) which noted that "the world of science literature has seen an astonishing sea change over the last fifteen or so years".[49]

2.2 Theoretical Approaches to Popular Science – Towards a Definition

The outline above of some of the historiographical studies of the popular science genre reveals significant disagreements about when popularization can be deemed to have 'begun'; however, these differences are really variations in the authors' conceptions of popularization itself. It is clear, reading, say, Burnham and Rousseau that they have dissimilar ideas as to what 'popular science' or 'popularization' really is, or what the process entails, but neither of them dedicate any space to elucidating their own definition. Bruce Lewenstein, in a brief overview of the historiography of popularization, identifies two categories of works that have considered popularization, and gives Burnham's book as a prime example of the first of these. This first strand "emerging mainly from attempts by single authors to survey broad periods of time, takes the notion of 'popularization' to be unproblematic – as the means by which the knowledge produced by scientists is distributed to audiences beyond the limits of professional research".[50] Rousseau, it would be fair to say, falls into this category also. On the other hand the second groups of works, mainly from the 1980s and 1990s, took "popularization not as a product, but as a process" and challenged "the sharp line between doing science and popularizing it".[51] Studies in this 'strand' ask vital questions about the definitions of popular science. Their interrogation of the assumptions about popular science, and some of their conclusions, will inform my own definition of popular science, and it is therefore to such studies that I wish to turn now.

I have had cause to mention, in the course of the previous historical contextualisation of popular science, the concept of the 'dominant view' of popular science, and the studies that have sought to overturn this view. It has now become compulsory in studies of popular science such as this one to include a similar rejection, drawing on Hilgartner, Whitley, and Cloître and Shinn,[52] of the

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48 Leane, p. 1.

49 Quoted in Broks, pp. 89-90.

50 Bruce Lewenstein, 'Popularization' in *Reader's Guide to the History of Science*, ed. by Arne Hessenbruch (London: Fitzroy Dearborn, 2000), pp. 586-588 (p. 586).

51 Ibid.

52 Hilgartner, 'The Dominant View of Popularization'; Whitley, 'Knowledge Producers and Knowledge Acquirers'; Michel Cloître and Terry Shinn, 'Expository Practice: Social, Cognitive and Epistemological Linkage', in *Expository Science: Forms and Functions of Popularisation*, ed. by Terry Shinn

traditional conception of popular science – to the extent that one wonders whether the dominant view is not now one that supports the realignment.[53] However, this overturning of an inflexible and often derogatory view of popularization is to be appreciated, even if the phrase 'dominant view' may well now be outdated (I will use the phrase 'traditional model' instead). Briefly, the traditional model of popular science involves two communities – the scientists and scientific institutions, and the public. Popular science is seen as a translation of the knowledge produced by the former community and absorbed by the latter, in a one-way passage of information. Furthermore, the process of popularization is seen as "at best, 'appropriate simplification' [...a]t worst popularization is 'pollution'", and yet is not seen as having any impact on the elite scientific community.[54] Hilgartner sees the conception of popular science as 'contaminated' as being a crucial corollary for the maintenance of the ideal of pure scientific knowledge, shoring "up an idealised view of genuine, objective, scientifically-certified knowledge" and also placing the judgement of which popularizations are "'appropriate' [...] and which are 'distortions'" in the hands of the scientific community.[55]

The primary criticism of the traditional model is the reductiveness of the process and of the formulation of the two communities: there is a far greater heterogeneity than is conceived in the traditional model. Firstly, the audience, the 'knowledge acquirers' in Whitley's phrase, are traditionally seen as "large, diffuse, undifferentiated and passive", but Whitley shows that parts of the audience exert an influence back upon scientific research and that (even excluding "the important set of audiences constituted by other scientists") they vary in levels of scientific knowledge.[56] In short "there are a number of readily identifiable audiences for scientific knowledge which pursue a variety of goals and which are important for scientific research in a number of ways".[57] Similarly, the scientific community is not a single monolithic entity, but a diverse conglomeration of groups, each with varying epistemological assumptions and experimental practices. The traditional idea of popular science translating between the scientists and the public has been eroded partly by the fact that "the expansion and specialisation of scientific research in the past 200 or so years has resulted in many scientists popularising their work to other groups of scientists as well as to non-scientists": specialisation has "increasingly necessitated intrascientific popularisation".[58] There is, to use Cloître and Shinn's phrase, "a sort

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and Richard Whitley, *Sociology of the Sciences Yearbook 9* (Dordrecht: D. Reidel, 1985), 31-60.

53 For example, see Greg Myers, 'Discourse Studies of Scientific Popularization: Questioning the Boundaries', *Discourse Studies*, 5 (2003), 265-79; or Leane, pp. 9-10.

54 Hilgartner, p. 519.

55 Hilgartner, p. 520.

56 Whitley, p. 4, p. 5.

57 Whitley, p. 5.

58 Whitley, p. 4, p. 10.

of expository continuum" of science writing, ranging through "specialist, inter-specialist, pedagogical and popular articles".[59]

Moreover, popular science covers not merely recognised scientific 'facts' but a full spectrum of knowledge from rarely disputed, long-held assumptions, through widely believed, but unproved, theories, to wild speculation and conjecture. Popular science often represents an expository space for ideas which are precisely *not* established; popular science's role as a forum for speculative theorisation, in a way impossible in a professional journal, can, and perhaps should, be seen as a vital one – especially for the cross-fertilisation of ideas within the scientific community. A. Truman Schwarz has asserted that "Popularization is [...] a way of going public with controversial opinions" and W. Daniel Hillis notes that popular science books often involve ideas "that have absolutely no way of getting published within the scientific community".[60] Dawkins recognises the importance of the genre when he reveals that his own books contain both "popularizations of material already familiar to scientists and original contributions to the field that have changed the way scientists think, albeit they haven't appeared in scientific journals".[61] Popular science writing, then, plays a role even in the construction of scientific knowledge. Jan Golinski, for example, argues that:

> As facts are translated from the language in which they are represented among specialists to language appropriate for a lay audience, they become consolidated as knowledge. As experts describe their findings to nonexperts, facts are simplified and rendered more dramatic, and the sureness with which they are held is strengthened, even among the experts themselves.[62]

2.3 Defining Popular Science

It has been necessary to use phrases such as 'popular science' and 'popularization' without defining them in order to conduct the preceding discussion, precisely because the definition of such terms requires a knowledge of some of the arguments and critiques, such as that of the 'dominant view', expounded above. I will briefly present distinctions between the terms that I intend to use in this thesis, for the avoidance of confusion. Therefore I take 'popular science' to

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59 Cloître and Shinn, p. 31, p. 32.

60 Quoted in Leane, p. 20; quoted in John Brockman, *The Third Culture* (New York: Simon & Schuster, 1995), p. 26.

61 Quoted in Brockman, p. 23.

62 Jan Golinski, *Making Natural Knowledge: Constructivism and the History of Science* (Cambridge: Cambridge University Press, 1998), p. 34.

mean science written primarily in an expository mode for a general, as opposed to specialist, readership. Bensaude-Vincent makes a distinction between 'popular science' and 'popularized science', seeing the former as, in the nineteenth century "a science distinct from that of professional science" and in the twentieth century as "the image of science as reflected by vehicles of pop culture such as commercial advertisements, best-seller fictions or television serials".[63] I, on the other hand, will use 'popularized science' and 'popularization' synonymously with 'popular science', but will make a distinction, following Sheets-Pyenson and George Basalla's definitions respectively, between the two representations of science conflated by Bensaude-Vincent.[64] Thus, I will use 'low science' to refer to non-professional science and scientific discourse; and I will refer to images of science in popular culture as 'pop science'. Clearly, as Sheets-Pyenson has said of the relationship between low science and popular science, the latter is generally contained within the former in the context of early- to mid-nineteenth-century popular science periodicals, popular science being simply the mode of communication of low science. By the late nineteenth century, and certainly in the twentieth century, as popular science publications sought to disseminate and explicate 'high' science, this relationship between popular science and low science had broken down. Whilst current popular science writing is not contained within high scientific discourse, nor is it necessarily part of low science either.[65] There is sometimes overlap too between pop science and popular science: some popular science books, the obvious example is *A Brief History of Time*, have become so well-known as to enter into popular culture.

A final phrase that needs clarification is 'public science'. Here I follow the succinct definition of Frank Turner who describes it as "the body of rhetoric, argument and polemic" employed by scientists to "justify their activities to the political powers and other social institutions upon whose good will, patronage, and cooperation they depend".[66] Here too, there is overlap with popular science, in that popular science books can often be deemed to be directly or indirectly involved with the justification of their particular field, or indeed the sciences in general. However, I will attempt to distinguish between publications whose primary role is expository (popular science) and those which are justificatory (public science).

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63 Bensaude-Vincent, p. 322.

64 Sheets-Pyenson; George Basalla, 'Pop Science: The Depiction of Science in Popular Culture', *Science and its Public: The Changing Relationship,* ed. by Gerald Holton and William A. Blanpied, *Boston Studies in the Philosophy of Science,* 33 (Dordrecht: D. Reidel, 1976), 260-78.

65 However, Danette Paul has shown how popular science works can indeed feed back into high scientific discourse. Danette Paul, 'Spreading Chaos: The Role of Popularizations in the Diffusion of Scientific Ideas', *Written Communication*, 21 (2004), 32-68.

66 Frank M. Turner, 'Public Science in Britain 1880-1919', *Isis*, 71 (1980), 589-601 (p. 589).

Almost any means of distinguishing popular science as a genre seems to fall at one hurdle or another. In terms of its historical construction as a genre, its inception seems to be based in the creation of something that is professional, or specialised, science; at the point at which scientists see the audience for their writings as predominantly other specialised scientists, rather than interested amateurs or the wider public, a genre of science writing that aimed to disseminate high science to a general readership could emerge. Finally, however, one has to conclude that there is an essential problem in creating a definition of a genre from an analysis of the members of that genre: there is a circularity of argument in trying to isolate the criteria that define a group, the members of which one has already chosen, based on a set of implicit criteria. In the end, the best one can do is accept that logically, definitions are atomic, or are shorthand for some defining properties or characteristics of previously defined objects. I have attempted to establish a collection of criteria that tend to define popular science, but with the caveat that many examples of the genre will display some but not all of these characteristics.

Popular science can take many forms, and find outlets in almost any media. Books and newspaper articles are only the most obvious of an array of means of dissemination: television documentaries, radio talks or programmes, public lectures, specialist popular science magazines, blogs, youtube videos. To address such a range is well beyond the scope of any single study; I will content myself with discussing published book-length works. The justification for this is fairly straightforward: since I will be comparing popular science with contemporary fiction it is book-length published works that, generically, most closely resemble modern novels, with their soft covers, back-cover blurbs and critics' reviews, chapters and epigraphs.[67] This superficial similarity is borne out by the use of metaphors, characterization and narrative; turning in the next chapter to popular science writing on the new physics I will show how several distinct sets of metaphors serve to support an account of the new physics that places considerable emphasis on the indeterministic implications of this set of related scientific theories.

[67] Baudouin Jurdant prefers to see popular science books as most closely related to autobiography, as opposed to fiction, since autobiography makes claims to truth in a way that fiction does not. Baudouin Jurdant, 'Popularization of Science as the Autobiography of Science', *Public Understanding of Science*, 2 (1993), 365-73. I agree that this may be an important distinction, but in other ways popular science books diverge from autobiography: they may range widely over time and between many different characters in a way less likely or common in autobiography, for example. The complex issue of fiction's relationship to truth will be raised in the conclusion to this thesis.

3 Representations of Determinism in Popular Science Writing on the New Physics

Gary Zukav's *The Dancing Wu Li Masters*, a seminal piece of popular science writing on the new physics that achieved a cult status in the 1970s, is composed of twelve 'Chapter 1's. The rationale, presumably, is to remind the reader of an exchange early in the book between Zukav and the T'ai Chi Master Al Huang on the structuring of the latter's classes:

> 'Every lesson is the first lesson,' he told me. 'Every time we dance we do it for the first time.'
>
> 'But surely you cannot be starting new each lesson,' I said. 'Lesson number two must be built on what you taught in lesson number one [...] and so on.'
>
> 'When I say that every lesson is the first lesson', he replied, 'it does not mean that we forget what we already know'.[1]

The exchange explains the conceit of the repeated Chapter 1s; but it is also analogous to the way in which Zukav wishes to present his subject, the new physics. The paradox of 'starting anew', but 'not forgetting what we already know' is similar to the problems that Zukav faces as he attempts to present the new physics (broadly, this means relativity and quantum mechanics) as a revolutionary overturning of classical, Newtonian, science. Zukav begins with the relatively equivocal position that "quantum mechanics does not replace Newtonian physics, it includes it" (*Wu Li*, 45), equivalent to 'not forgetting what we already know'; but already by the end of the first Chapter 1 he sums up, "The physics of Newton was a thing of the past." (*Wu Li*, 90) It is to this latter position – that of starting anew – that Zukav defaults in the remainder of the book as he characterises the new physics not as a continuation of classical physics, but a rejection of it.

The exchange also epitomises the paradoxical form of thinking that Zukav will emphasise is required to come to terms with the conclusions with which quantum mechanics presents us. More specifically, the duality of starting anew but not forgetting the previous lessons can be compared to the conceptual problem of accepting complementarity – that a photon or electron can behave like a particle in one experimental situation and like a wave in another.

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1 Gary Zukav, *The Dancing Wu Li Masters* (London: Fontana, 1979), p. 36. All subsequent references are to this edition, hereafter *Wu Li*, and will be made in the text.

In his rejection of Newtonian mechanics Zukav is not alone. Fritjof Capra, Stephen Hawking, John Gribbin, Brian Greene, and others all identify modern physics' theories of relativity and quantum mechanics as a fundamental break with Newtonian science.[2] Popular science figures the shift from classical mechanics to the new physics as a revolution in science: Greene describes first how "the constancy of light's speed spelled the downfall of Newtonian physics" and then how the development of quantum mechanics "spell[ed] the downfall of what has come to be known as classical physics";[3] Zukav speaks of "the end of the line for classical causality" (*Wu Li*, 88) as a result of the wave-particle duality, and sees "the whole idea of a causal universe [as] undermined by the uncertainty principle" (*Wu Li*, 135); Capra puts it in no uncertain terms – "Quantum theory has thus demolished the classical concepts of solid objects and of strictly deterministic laws of nature".[4]

What is conspicuous in the above quotations is the uncritical yoking of distinct concepts. Zukav's pairing of "classical" and "causality" silently equates the two ideas; a similar slippage is evident in Capra's implication that "deterministic laws of nature" are a classical concept, irrelevant to modern physics. Greene is initially more cautious: he describes how the constancy of light's speed "ultimately spells doom for another venerable and cherished theory – Newton's universal theory of gravity" (*Elegant Universe*, 52), but resists the temptation to extrapolate to implications for more general ideas of determinism or causality. But finally he too succumbs to patronising a distinctly Laplacian sounding determinism, one that, he implies, has been superseded: "By 1927, therefore, classical innocence had been lost. Gone were the days of the clockwork universe whose individual constituents were set in motion at some moment in the past and obediently fulfilled their inescapable uniquely determined destiny" (*Elegant Universe*, 107).

These conflations are an important part of the representation of a revolutionary overturning of classical physics: Newtonian mechanics comes to stand, metonymically, for determinism and even causality. Newtonian physics and determinism, together or separately, are established as representatives of the now obsolete. The *process* of the scientific revolution of relativity and quantum mechanics may be represented as the exposure of the limits of Newtonian mechanics, but it is a deterministic world-view that is figured as the principle casualty. And yet it is unclear

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2 Although the new fields of chaos and complexity are often presented by popularizers in a similar way, I will concentrate on popularizations of the new physics, with only occasional references to chaos, though many of the arguments also apply to popularizations of these fields.

3 Brian Greene, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (London: Jonathan Cape, 1999), p. 33, p. 90. All subsequent references are to this edition, hereafter *Elegant Universe*, and will be made in the text.

4 Fritjof Capra, *The Tao of Physics* (London: Fontana, 1981) p. 71. All subsequent references are to this edition, hereafter *Tao*, and will be made in the text.

quite what this 'determinism' so resoundingly "demolished" (*Tao*, 71) by the new physics *is*: none of these authors establish an explicit definition of 'determinism', apparently presuming the term to be unproblematic; but an established definition is essential since, as Bricmont notes, "Determinism is one of those words over which many people get involved in disputes, partly because it is rarely defined".[5]

It is important at this stage to clarify quickly what this critique will not be doing: I will not attempt to show that a non-deterministic argument based on the theories of relativity and quantum mechanics is *wrong* by asserting that a deterministic world view is compatible with quantum mechanics. This thesis does not seek to make such a critical intervention into philosophy of science, or quantum theory. Rather I will interrogate the *representations* of scientific theories and practice in popular science writing. As such, my contention is that, even while the theories of the new physics may have consequences for determinism (however we understand the term), the emphasis placed by popular science writing on the new physics upon the demise of determinism and the resultant implications is striking. This focus is achieved both through explicit arguments and statements and, I will argue, through a range of literary devices.

To this end, the slippery use of the word 'determinism' is significant for two reasons. Firstly, because as noted above, the claim that determinism has been overthrown by the new physics is weakened when the precise meaning of determinism is left unclear. Secondly, and more significantly, because if the reader is unclear what is connoted by 'determinism' then the opposition established between the supposedly very different relationships that classical physics and the new physics have with determinism may collapse. In other words, if classical physics is presented as supporting one form of determinism, and the new physics apparently rejects a different form of determinism, then assertions that the new physics has overthrown the classical world view are severely undermined. A related issue concerns the misinterpretation of historical understandings of determinism – just as an ill-defined idea of determinism may erode the opposition created between classical physics and the new physics, so may a misunderstanding of the way in which determinism was conceived by classical physicists. This is especially true of Laplace's famous lines on universal determinism, routinely misinterpreted by writers establishing a gulf between classical and modern attitudes to determinism.

In this chapter I will examine the strategies in the rejection of determinism in popular science writing on the new physics, concentrating in particular on that essential element in the pedagogy

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5 Jean Bricmont, 'Determinism, Chaos and Quantum Mechanics', <http://www.freeinfosociety.com/pdfs/mathematics/determinism.pdf> [accessed May 23 2007].

of popularisations – metaphor. I will argue that the presentation of the new physics as a departure from deterministic laws involves three supporting arguments, and that each of these is in turn buttressed by the systematic use of a particular metaphor or range of related metaphors. The first emphasises the role of human consciousness in the new physics. This foregrounding of consciousness is, I will show, implicit in the repeated use of anthropomorphic metaphors. The second establishes an opposition between the old and the new physics, presenting non-determinism as a consequence of scientific revolutions and progress. This image of scientific progress is reinforced by the numerous forms of metaphors involving exploration and maps. The third and final element of the anti-determinism of these popular science books consists of the assertion of the inherent indeterminism in quantum mechanics. This third argument for indeterminism is supported, in the popular science books I will examine, by metaphors which draw on the cultural history of the image of the shadow.

3.1 Anthropomorphic Particles

The reactions to Laplace's famous lines on the theoretical possibility of universal determinism give us an insight into the motivation behind figuring the new physics as a break with Newtonian mechanics. Capra, Greene, Gleick, and Stewart all quote the lines describing how "an intelligence which could comprehend all the forces by which nature is animated" and "submit these data to analysis [...]; for it, nothing would be uncertain and the future, as the past, would be present to its eyes".[6] As with Greene's description of a clockwork universe quoted above, there is a patronising attitude evident in responses to Laplace – Stewart talks about the "intellectual sleight-of-hand" involved, but also allows for "the atmosphere of excitement that prevailed in the science of the time";[7] Gleick goes further, describing how Laplace "caught Newtonian fever like no one else" and proposing that now "Laplace seems almost buffoon-like in his optimism".[8] But it is perhaps Zukav's response that is most revealing – not specifically to Laplace, but to the laws of motion of the old physics on which Laplace rested his apparent assertion of universal determinism:

> [they] carry within them a very dispiriting logic. If the laws of nature determine the future of an event, then, given enough information, we could have predicted our present at some time in the past. (*Wu Li*, 51)

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6 Laplace, p. 4.

7 Ian Stewart, *Does God Play Dice?: The New Mathematics of Chaos*, 2nd Ed. (Harmondsworth: Penguin, 1997), p. 6.

8 Gleick, *Chaos*, p. 14.

There is a deep reluctance to accept the complete determinism supposedly implied by the old laws and this is, I believe, a key impetus behind the opposition created between the old and the new physics: as Hoefer observes, "what is at stake in determinism [is...] our fears about our own status as free agents in the world".[9] Bricmont has noted that "[m]any people simply cannot swallow mechanical and reductionist explanations"; the philosophy of determinism seems to disagree with our intuitive sense that we have a conscious choice whether we do X or Y.[10] Popular science writing on the new physics utilises this opposition between determinism on the one hand, and conscious choice on the other; Newtonian mechanics is equated with the former, whilst a link is made between the new physics and consciousness. How this latter connection between the new physics and consciousness is created will be the subject of this section.

Summarising the supposed implications of classical physics, Zukav claims that if we

> accept the mechanistic determination of Newtonian physics – if the universe really is a great machine – then from the moment that the universe was created and set into motion, everything that was to happen in it already was determined. (*Wu Li*, 51)

The first part of this interpretation of Newtonian physics directly equates mechanistic determinism and Newtonian physics; in the immediately following sentence, imagining this deterministic world, Zukav simultaneously introduces the counter-argument of the presence of free will:

> we may seem to have a will of our own and the ability to alter the course of events in our lives, but we do not. Everything, from the beginning of time, has been predetermined, including our illusion of having a free will. (*Wu Li*, 51-52)

The debate ostensibly concerns scientific determinism, but the focus is subtly shifted through the proliferation of first-person pronouns in this second passage (five in two sentences), a proliferation all the more evident when contrasted with their absence from the immediately preceding lines quoted above. This new focus opposes scientific determinism to free will and the importance of human consciousness. Zukav has laid a logical foundation such that if he can show that we do have the "ability to alter the course of events", and more generally emphasise the role that consciousness plays, then Newton's supposed mechanistic determinism appears to be undermined.

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9 Hoefer, (Section 1, Introduction).

10 Jean Bricmont, 'Science of Chaos of Chaos in Science?', *Physicalia Magazine*, 17 (1995) <http://www.chronos.msu.ru/EREPORTS/bricmont.htm> [accessed 24 May 2007], 159-208.

Initially, however, Zukav's refutation of determinism seems to rely upon showing that "quantum mechanics does not and cannot predict specific events" (*Wu Li*, 53). Following the discussion of the Great Machine quoted above Zukav goes on to examine the problem of prediction:

> The Great Machine runs blindly on, and all things in it are but cogs.
>
> According to quantum mechanics, however, it is not possible, *even in principle*, to know enough about the present to make a complete prediction about the future. (*Wu Li*, 52)

The almost paratactical juxtaposition of the dismal prospect of our merely illusory free will implied by Newtonian mechanics, and the impossibility of prediction asserted by quantum mechanics, implies that the former is called into question, or even refuted, by the latter, an implication especially evident in that "however". This refutation rests upon a slippage between determinism and prediction criticised by both Jean Bricmont and John Earman. The problem, Bricmont claims, is that "nobody who has ever defended universal determinism (in particular Laplace [...]) ever meant it to be true in that sense of the word. Everybody agrees that not everything in the world is predictable, and it is somewhat surprising to see how many people present that truism as if it were a recent discovery".[11] Earman disagrees with Bricmont in that he sees Laplace as outlining a definition of determinism which "starts with a causal flavor but ends by equating determinism with predictability".[12] But he agrees that we must resist stirring "ontology and epistemology [...] into a confused and confusing brew". For Earman, prediction can never form the basis of a definition of determinism: "[Determinism] is an ontological vision; whether it is fulfilled or not depends only on the structure of the world, independently of what we do or could know of it".[13] As Carl Hoefer concludes:

> 'Predictability' is therefore a *façon de parler* that at best makes vivid what is at stake in determinism; in rigorous discussions it should be eschewed. The world could be highly predictable, in some senses, and yet not deterministic; and it could be deterministic yet highly unpredictable, as many studies of chaos (sensitive dependence on initial conditions) show.[14]

In the end, however, Zukav does not make prediction the focus of his assertions that determinism has been undermined. Instead his refutation focuses on the connection between the new physics and consciousness, and I will identify three ways in which this connection is made and reinforced. The first, and most explicit, is the emphasis on the role played by the observer in

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11 Bricmont, 'Determinism, Chaos and Quantum Mechanics'.
12 John Earman, *A Primer on Determinism* (Dordrecht: D. Reidel, 1986), p. 7.
13 Ibid.
14 Hoefer, (Section 1, Introduction).

quantum mechanics. Universal determinism, at least as it is defined by Zukav, Capra, and others, is supposedly disproved by the conscious choices made by human observers:

> the two data that must be included in a Newtonian calculation, position and momentum, cannot both be known with precision. *We must choose*, by the selection of our experiment, which one we want to measure most accurately[.] (*Wu Li*, 53)

and on the very next page, "*we must choose* which of these two properties we want to determine" (*Wu Li*, 54). The italics clearly emphasise the importance of the observer's choice. Zukav goes further, claiming that "Not only do we influence our reality, but, in some degree, we actually *create* it [...] Metaphysically, this [choosing which property to measure] is very close to saying that we *create* certain properties because we choose to measure these properties." (*Wu Li*, 53-4) Likewise, Capra scatters the word "consciousness" throughout his discussion of the role of the observer:

> In Eastern mysticism, this universal interwovenness always includes the human observer and his or her consciousness, and this is also true in atomic physics [...] The end of this chain of processes [of preparation and measurement] lies always in the consciousness of the human observer. Measurements are interactions which create 'sensations' in our consciousness[.] (*Tao*, 144)

These explicit references to the association between consciousness and, for example, the uncertainty principle, are supported, as Elizabeth Leane has comprehensively shown, by "a network of interlocking metaphors, all of which identify quantum theory with the human mind".[15] This is the second strategy for linking the new physics with conscious choice, and thus placing it in opposition to the determinism of classical physics. Leane concentrates on the pervasive metaphor of the "dance", showing that "[t]he dance metaphor establishes an implicit connection between quantum phenomena and consciousness".[16] But equally, the frequent anthropomorphic metaphors describing quantum processes in terms of human consciousness also reinforce the explicit connection that is made. When John Gribbin explains that "electrons not only know whether or not both holes are open, they know whether or not we are watching them",[17] or when Bill Bryson describes how "certain pairs of subatomic particles [...] can each 'know' what the other is doing",[18] or when Richard Feynman asks "How does a photon "make up its mind" whether it should go to A or B?"[19] – in all these cases there is clearly a level of anthropomorphism equal to or greater than in describing, for example, genes as 'selfish' (see

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15 Leane, p. 162.
16 *Ibid.*
17 John Gribbin, *In Search of Schrödinger's Cat* (London: Corgi Books, 1985), p. 171.
18 Bryson, p. 191.
19 Richard P. Feynman, *QED: The Strange Theory of Light and Matter* (London: Penguin Books, 1990), p. 18.

below, chapter 5.1). However, following Gillian Beer's argument that it is context that determines whether metaphors "overturn the bounds of meaning assigned to them",[20] I contend, as Leane does, that the anthropomorphic metaphors used by Capra and Zukav are more problematic than those of Gribbin, Feynman or Bryson. Because Zukav makes explicit connections between consciousness and quantum physics, when he tells his reader that "photons in the double-slit experiment somehow "know" whether or not both slits are open" (*Wu Li*, 88) there is greater potential for his anthropomorphic metaphor to assume a meaning beyond the metaphorical. 'Scare quotes' do little to counteract this, and indeed sometimes he drops them altogether: "*How did the photon in the first experiment know that the second slit was not open?*" (*Wu Li*, 87).[21] The same problem arises in Capra's *The Tao of Physics*. When he describes how fast moving particles "live about 1.7 times as long as their slow 'twin brothers'" (*Tao*, 178) or when he writes about the "particle's point of view" (*Ibid.*) the subject of the new physics' study is endowed with human characteristics, shoring up the link between the new physics and conscious choice.

I have deliberately ignored possibly the most obvious link between the new physics and consciousness established in these two texts, by Zukav and Capra – the extended parallel between Eastern mysticism and the new physics. Sal Restivo's articles conduct an extensive analysis of "the thesis that there are parallels between modern physics and Eastern mysticism" with particular attention paid to Capra, and I will not rehearse the arguments here.[22] Whilst acknowledging the role that this parallelism plays in the connection between the new physics and consciousness, I will concentrate here instead on the importance of metaphor, in order that this analysis retains applicability to a wider range of popular science books addressing the new physics, beyond those that make a connection with Eastern Mysticism.

The argument, that such a system of anthropomorphic metaphor works in implicit support of explicit connections made between the new physics and consciousness, and thus plays an important role in presenting the new physics as a revolutionary rejection of determinism, involves an assumption about the role of metaphor in these books. This is representative of a set of wider assumptions on which the readings in this thesis rest. It is tempting to see many metaphors as simply an inevitable consequence of the expository mode of popular science writing – pedagogical metaphors that, albeit maybe imperfectly, convey a difficult technical idea or theory

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20 Gillian Beer, *Open Fields: Science in Cultural Encounter* (Oxford: Clarendon Press, 1999), p. 156.

21 This same 'dropping' of scare quotes occurs elsewhere too. Cf. Gribbin, p. 171.

22 Sal Restivo, 'Parallels and Paradoxes in Modern Physics and Eastern Mysticism: I – A Critical Reconnaissance', *Social Studies of Science*, 8 (1978), 143-81; Sal Restivo, 'Parallels and Paradoxes in Modern Physics and Eastern Mysticism: II – A Sociological Perspective on Parallelism', *Social Studies of Science*, 12 (1982), 37-71.

without recourse to the language and mathematics in which the ideas are expressed in their technical form. These pedagogical metaphors constitute the first of three categories into which we could divide the metaphors in popular science books, which I will outline here. Readers and critics should, I believe, remain healthily sceptical of metaphors in popular science, not dismissing them too quickly into this first category. Leane identifies as "naive" a similar temptation "to dismiss the narrative structure of science popularizations as mere pedagogical scaffolding".[23] More broadly, I believe that popular science writing can and should be subjected to the same analysis as other textual discourse. A choice is made by the author when a photon is said to "know" whether both slits are open: to recall to Whitley's pithy conclusion, "[e]xpository practices are not epistemologically neutral".[24]

A second category of metaphors, overlapping with the first, is composed of metaphors drawn consciously or unconsciously from elsewhere. Clearly, these can be pedagogical as in the first category; the significant difference is that they also invoke, explicitly or implicitly, the tradition from which they are drawn. An example will demonstrate this most efficiently. Einstein's famous lines from his letter to Max Born (12th December 1926) engendered a lasting metaphor:

> Quantum mechanics [...] is not yet the real thing. The theory says a lot, [...] but [it] does not really bring us any closer to the secret of the Old One. I, at any rate, am convinced that He does not throw dice.[25]

Einstein's iconic status (and the fact that he used the image repeatedly)[26] has ensured that this metaphor has been ubiquitous in popular science books on the new physics.[27]

Clearly, as he used it, Einstein's metaphor is not motivated by pedagogy; after all, his letters were addressed to fellow physicists. Nor is it pedagogical when used second-hand by popular science writers, for the image of 'God playing dice with the universe' (as it is often rendered) is far from the most obvious way to explain the random element of quantum mechanics. Indeed, this image was already a strategic misrepresentation of quantum mechanics when used by Einstein. Einstein was unhappy about the "limitation on the physicist's degree of certainty" as a result of Heisenberg's uncertainty principle; but in his image of God playing dice "Einstein is cheating [...]; he metaphorizes the implication of quantum theory in a limiting way".[28] Its use by popularizers is

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23 Leane, p. 182.
24 Whitley, p. 11.
25 Quoted thus in Ronald W. Clark, *Einstein: The Life and Times* (New York: HarperCollins, 1971), p. 340.
26 Cf. Clark, p. 345, p. 346.
27 See, for example, Stewart, *Does God Play Dice?*; L.I. Ponomarev, *The Quantum Dice*, trans. by A.P. Repiev (Bristol, Philadelphia: Institute of Physics, 1993); *Wu Li,* p. 92.
28 Arlen J. Hansen, 'The Dice of God: Einstein, Heisenberg, and Robert Coover', *NOVEL: A Forum on*

motivated, then, by the fact that it is a metaphor with a rich cultural pedigree, invoking Einstein's disagreement with the chance element in quantum mechanics.

In line with my own argument, I would suggest also that the use of this memorable image of 'God playing dice' supports the non-deterministic representation of the new physics advanced by these popular science books. Of course, Einstein originally used the metaphor in the negative – that God 'does not throw dice' – but the enduring element of the metaphor is the chance and randomness evoked by the dice themselves.

Isolating these 'adopted' metaphors in a separate category in no way removes them from the literary critical approach proposed for expository metaphor. Just as a literary critic should not assume that metaphors are merely pedagogical, so it should not be presumed that metaphors in this second category are adopted neutrally – on the contrary, the adoption of a particular tradition of metaphor can be extremely revealing. I have discussed elsewhere, for example, how popular science writers' use of Rutherford's image of "a fly in a cathedral" as a model for the atom appropriates the cultural status of religion.[29] Similarly Knusden has explored in detail the passage of the metaphor of the genetic 'code' from scientific texts to popular science writing.[30] I will perform a more detailed analysis of this form of metaphor later to show how the use of metaphors involving shadows invoke the long cultural history associated with this image, and how this is utilised by popular science writers.

The third type of metaphor, and the most interesting for my purposes, is that characterised by Gillian Beer as strategic, one that can be shown to be working towards and within an agenda that becomes evident through literary analysis of the metaphor, and from the context in which it is placed.[31] Obviously, metaphors from the previous categories may also inhabit this one: explanatory metaphors may also advance, say, a particular view of scientific progress, or the scientific method; similarly, adopted metaphors may carry significant resonances which support the advocated position. It is into this final category that I place many of the anthropomorphic metaphors that attribute human consciousness to non-conscious sub-atomic particles, implicitly supporting, as they do, the link established between the new physics and consciousness as part of the broader aim to undermine the perceived universal determinism of classical physics.

Fiction, 10 (1976), 49-58 (p. 50).

29 My own unpublished M.Phil. thesis. 'The Literature of Evolution: Narrative, Metaphor and Teleology in Richard Dawkins and Stephen Jay Gould', University of Cambridge, 2005.

30 Susanne Knudsen, 'Scientific Metaphors Going Public', *Journal of Pragmatics*, 35 (2003), 1247-63.

31 Gillian Beer, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot, and Nineteenth-Century Fiction* (London: Routledge, 1983), p. 57. All subsequent references are to this edition, hereafter *DP*, and will be made in the text.

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I claimed, above, that there are three ways in which popular science writers connect the new physics to consciousness. Firstly, I identified explicit statements of this connection, concentrating primarily on the role of the consciousness of the observer. Secondly, I claimed that the strategic use of metaphors implying the consciousness of sub-atomic particles supports this connection. The third strand in the argument looks at the connection from the other direction: not the impact of consciousness on our understanding of physics, but the supposed impact of the new physics' revolutions on our understanding of consciousness.

There is an elision between the claims that consciousness plays a crucial role in the new physics, that the new physics takes consciousness as part of the object of its study and finally that the new physics' theories have implications for our understanding of consciousness. The first stage of this elision is accomplished by passages such as the following:

> Now, after three centuries, the Scientists have returned with their discoveries. They are as perplexed as we are [….]
>
> "We are not sure," they tell us, "but we have accumulated evidence which indicates that the key to understanding the universe is *you*."
>
> (*Wu Li*, 115)

The hyperbolic phrase "key to understanding the universe", coupled with the suggestion that this conclusion is the result of (three centuries of) experimentation implies that consciousness is more than simply important in our understanding of physics, but that the study of consciousness *is part of* physics. This is stated more explicitly later:

> The Cogs in the Machine have become the Creators of the Universe.
>
> If the new physics has led us anywhere, it is back to ourselves, which, of course, is the only place we could go. (*Wu Li*, 136)

The declaration here is that, following the revolutions brought about by relativity and quantum mechanics, physics does take "ourselves" as a subject of study, or at least contemplation – 'we' are incorporated into its world-view.

The second shift, from the study of consciousness within physics, to physics' implications for consciousness, is facilitated by the speculation that the traditional objects of physics' study are themselves conscious. The curious logical leap-of-faith required in Zukav's remarkable claim that

"there is a possibility that by studying photons [...] we may learn something about us" (*Wu Li*, 88) is at least partly achieved through the cumulative effect of the anthropomorphic description of photons: the metaphorical identification of photons as entities that "know" and "act accordingly" prepares the reader for the jump to the claim that "Some physicists, like E.H. Walker, speculate that photons may be *conscious*!" (Ibid.). Zukav does at least mark the sensationalism with an exclamation mark here, but his ostensible retreat to a more conservative position – "Whether Walker is correct or not" – is actually nothing of the sort:

> We have little choice but to acknowledge that photons, which are energy, do appear to process information and to act accordingly, and that therefore, strange as it may sound, they seem to be organic. (*Wu Li*, 88)

Having 'shown' that photons are organic (in this very dubious sense) Zukav is able to conclude that "since we are also organic" the study of photons could lead to revelations about ourselves.

The close association of the new physics and consciousness plays an important role in the representation of the new physics as non-deterministic. Determinism is seen to preclude the possibility of conscious choice affecting a deterministic universe, and therefore the inclusion of consciousness within the framework of modern physics undermines the supposed determinism of Newtonian mechanics. However the connection also has the secondary consequence of 'proving' that physics has an impact on our understanding of ourselves, an important factor in the success of popular science books. To this end, the numerous ways in which determinism is questioned and rejected that I identify in this chapter are a means of supporting the "claims that quantum mechanics has heralded a return to an anthropocentric world-view" by prioritising the role of human consciousness, and thus form part of the representation of the new physics as having "restore[d] humanity to centre stage after four hundred years of post-Copernican exile".[32]

3.2 Exploring Progress

In the previous section the anti-deterministic argument was seen, in the opposition created between determinism on the one hand and consciousness on the other, to also inevitably involve a parallel opposition between classical physics and the new physics. In this section I will focus in more detail on this latter opposition, and on the metaphors of exploration that support the argument that the new physics represents a critical moment in scientific progress, and supersedes the determinism of classical physics.

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[32] Leane, p. 135, p. 159.

Put simply, scientific progress in popular science books on the new physics is often figured spatially – or more precisely, territorially. New and revolutionary science is analogous to exploring or discovering new territory, as when Einstein is described as stepping "boldly into the unknown, in fact, into the unimaginable. Already on new territory, he proceeded to explore where no person had ever been before" (*Wu Li*, 159) or when Brian Greene describes how "Physicists focused their initial pathbreaking efforts to merge special relativity with quantum concepts" (*Elegant Universe*, 121).[33] Other examples abound: Zukav describes the most innovative physicists as "those who best have slipped the bonds of the known to venture far into the unexplored territory which lies beyond the barrier of the obvious" (*Wu Li*, p140); Martin Gardner, referring to the Mandelbrot set, but scientific discoveries more generally, claims that it is "as much 'out there' as Mount Everest is, subject to exploration in the way a jungle is explored";[34] Einstein, in a comparison also quoted in *The Dancing Wu Li Masters*, likens "creating a new theory [...to] climbing a mountain" and imagines the "mastery of the obstacles on our adventurous way up".[35]

Thus known territory is equated with established scientific theory and exploration stands for pushing back the boundaries of existing knowledge.[36] On the simplest level, metaphors of territory, exploration, maps and so on, established as representative of the process of scientific advancement and used in conjunction with the scientific discoveries of the new physics, support the argument that the new physics, as a scientifically more 'advanced' theory, supersedes classical physics. But there are a number of secondary implications that result from this system of metaphor that have consequences for the representation of scientific progress in general and the new physics in particular. The first is a ramification of the very nature of metaphors, whereby attributes of the 'vehicle' of the metaphor transfer themselves across to the 'tenor', to borrow I.A. Richards's terminology.[37] In the case of exploration the primary attribute transferred across to scientific progress is that of expansion: the expansion of territory implies the expansion of

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33 The subtitle to Greene's book on string theory is "Superstrings, *Hidden* Dimensions and the *Quest* for the Ultimate Theory" (italics mine).

34 Foreword to Roger Penrose, *The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics* (Oxford: Oxford University Press, 1989), p. xv.

35 Albert Einstein and Leopold Infeld, *The Evolution of Physics* (Cambridge: Cambridge University Press, 1971) p. 31, and also quoted in Zukav, p. 45.

36 Feynman provides an interesting counter-example, using a spatial metaphor of "retreat" to describe the 'advances' of new physics: "Does this mean that physics [...] has been reduced to calculating only the *probability* of an event, and not predicting exactly what will happen? Yes. That's a retreat, but that's the way it is" (Feynman, *QED*, p. 19).

37 In I.A. Richards's terminology the 'tenor' of a metaphor is the subject to be described, the 'vehicle' is that to which the subject is compared. E.g. 'The setting sun [tenor] was a red ball [vehicle] in the sky'. See I.A. Richards, *The Philosophy of Rhetoric*, ed. John Constable (London: Routledge, 2001; first published 1936), p. 64.

knowledge. But the vehicle of a metaphor may, and almost always does, evoke more than one association, and there are secondary associations that also affect the representation of scientific progress through these metaphors of exploration and territory.

The most interesting of these is probably the relationship between the *act* of exploration and the *act* of 'discovering' a new scientific theory. In describing scientific progress in terms of exploration, some of the ideas commonly evoked by the image of exploration, from the "*system of associated commonplaces*" as Max Black refers to it, are transferred to scientific progress.[38] Let us look at an example:

> such reasoning has inspired a prodigious and distinguished group of physicists to follow this path vigorously, but the terrain has proven to be fraught with danger, and no one has succeeded in traversing it completely. (*Elegant Universe*, 126)

Here, the exploration metaphor does not just imply the expansion of scientific knowledge but also the manner of this expansion: scientific research and practice are presented as arduous – despite their vigorous attempts the dangerous terrain is still not traversed. To read this carefully is to realise that the "vigorous" efforts of the scientists may be just as metaphorical as the idea that their attempt to develop a scientific theory is literally the crossing of dangerous terrain, but something of the vehicle (the effort involved) transfers to the tenor (scientific practice). It is easy to unpick this example, to reveal the transferred commonplaces, because they are made explicit; the dangers, the vigorous efforts – these are the associations we have with exploration, built up from cultural representations over centuries. But, I argue, these associations are implicit *and transferred* to the representation of scientific practice even when they are not made explicit by the writer. Taking the initial examples quoted above in turn, the implied dangers, difficulties and effort involved in scientific work are implicit in the following words or phrases: "boldly", "unknown", "new territory" and "where no person had ever been before"; "venture far", "unexplored territory" and "lies beyond"; in Gardner's image the arduousness of 'discovering' is simply contained in the choice of places he uses analogously – Mount Everest and a jungle; in Einstein's image a mountain is again chosen, and the difficulties are also present in the words "obstacles" and "adventurous". This implication of the arduousness of exploration is paralleled in explicit declarations of the similar effort involved in scientific endeavour, as when Greene describes how "a few dedicated researchers kept at it" and produced the "landmark paper culminating more than a dozen years of intense research" (*Elegant Universe*, 137, 138); even the

[38] Max Black, *Models and Metaphors: Studies in Language and Philosophy* (Ithaca, New York: Cornell University Press, 1962), p. 40.

graduate students "worked deep into the night to try to master the vast areas of theoretical physics and abstract mathematics" (*Elegant Universe*, 139).

There is another 'commonplace' associated with exploration, I believe; one perhaps less obvious at first, but borne out by examples from these popular science texts. This other feature of exploration is the possibility of moments of almost mystical wonder, like that experienced by "stout Cortez" in Keats's sonnet *On First Looking into Chapman's Homer* "when with eagle eyes / He star'd at the Pacific", a moment that renders him silent. These, no doubt mythic, but identifiable, moments of discovery – bursting through the jungle to see a hidden temple, attaining a summit and seeing the vista laid out ahead – equate to that other mythic moment in scientific practice, the 'eureka moment'. The connection between these moments in exploration and moments of discovery in science is, like the associations of arduousness, only sometimes explicit – as in Einstein's comparison quoted above in which as we climb (create a new theory) we gain "new and wider views, discovering unexpected connections" – but is always partially present. The importance of this eureka moment in popular science representations of scientific practice is beyond question. Capra asserts that "Scientists are familiar with direct intuitive insights from their research, because every new discovery originates in such a sudden non-verbal flash" (*Tao*, 40) and Greene describes how "In 1900 Planck made an inspired guess" (*Elegant Universe*, 91). The essential element in these moments of insight is that they are precisely that – moments. The gradual realisations that are part of scientific practice are dramatically compressed: Greene imagines "the key insight that Einstein had one happy day in the Bern patent office" (*Elegant Universe*, 60); similarly, Zukav, telling "the story" of Young's double-slit experiment, pronounces, "When both slits were uncovered, however, Young made history" (*Wu Li*, 85).

Taken together, these two shared representations of, on the one hand, exploration and, on the other, the practice of science and the history of science, constitute the narrative model of scientific discovery that I will explore further in chapter 5. This model involves initially long and arduous work or research (often of a mechanical or repetitive nature), culminating in a 'eureka moment'. Whilst science writers sometimes explicitly deny the veracity of this model, the temptation to utilise it in narratives of scientific discovery is strong.[39] Popular science books tend to opt for this 'hard-graft and eureka' model over the standard normative history of "development-by-accumulation" that Thomas Kuhn identifies in science textbooks.[40] Of course,

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39 Stephen Jay Gould might show such self-awareness in claiming that "Key moments are kid stuff. [...] I have laboured to master all the details and to arrange them in proper order. How can I now blow all this effort on the myth of eureka?", but there is no mistaking his adherence to this exact narrative model at other times. Gould, *Wonderful Life*, pp. 129-30.

40 Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd Ed. (Chicago: University of Chicago Press,

Kuhn expresses "profound doubts about the cumulative process through which these individual contributions to science were thought to have been compounded" and concludes that it is "difficult to see scientific development as a process of accretion"[41] – but the eureka structure is even more misleading.

Another form that territorial metaphors may take, besides exploration, is that of maps. If, in metaphors of exploration, territory represents existing knowledge and exploration the pushing back of the boundaries of knowledge, map metaphors tend to take terrain as representing nature, the world or the universe and maps as our knowledge of nature. As with metaphors of exploration, it is important to establish the particular elements of the "system of associated commonplaces" that are being utilised when this vehicle is pressed into service. Maps, I contend, are used as a metaphor for scientific knowledge because they themselves are a representation that is simultaneously useful and limited or imperfect; this latter quality is emphasised by Capra (who is fond of this metaphor), as part, I argue, of the demonstration that the new physics has shown the impossibility of science's complete knowledge of the world and is thus non-deterministic.

The first map analogy in *The Tao of Physics* makes it clear that this imperfection of representation is at the heart of the metaphor:

> In thinking about the world we are faced with the same kind of problem as the cartographer who tries to cover the curved face of the Earth with a sequence of plane maps. We can only expect an approximate representation of reality from such a procedure[.] (*Tao*, 28)

Capra goes on to compare this approximation to the field of science, saying, "The limitations of any knowledge obtained by these [scientific] methods have become increasingly apparent in modern science, and in particular in modern physics" (*Ibid.*). On this level the metaphor is fairly self-explanatory; however, having established maps as repositories of scientific knowledge, their connection with the wider theme of consciousness is brought to the fore. After all, maps are human constructs; or, as Capra puts it, "Modern physics has confirmed [that…] the concepts we use to describe nature are limited, that they are not features of reality, as we tend to believe, *but creations of the mind*; parts of the map, not of the territory." (*Tao*, 167. Italics mine). Capra frequently uses Alfred Korzybski's distinction between 'the map and the territory' to argue that science's knowledge of the world is imperfect and incomplete. Often this is done explicitly, as in the example above, or when asserting that "mathematics […] must be seen as part of our

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1970), p. 2.

41 Kuhn, p. 3.

conceptual map and not as a feature of reality itself." (*Tao*, 33). But increasingly this idea is implicit in the map metaphor: when Capra notes that "Our notions of space and time figure prominently on our map of reality" (*Tao*, 167) only the word "notions" and the metaphor of the map (now thoroughly integrated) indicate that these are, according to Capra, not properties of nature, but creations of our consciousness.

Capra's use of the map metaphor may be usefully compared to Borges's wonderful short story describing "a Map of the Empire whose size was that of the Empire, and which coincided point for point with it", eventually deemed "Useless" by succeeding generations and "delivered up to the Inclemencies of Sun and Winters" until only "Tattered Ruins of that Map" remain.[42] The target of the pathetic allegory of this pointless map might be more open to speculation, were it not for Borges's title – 'On Exactitude in Science' (or 'On Rigour in Science' – the Spanish title is 'Del rigor en la ciencia'). Like Capra's analogies, Borges's story may be read as revealing the essential absurdity in trying to 'map' our epistemological systems onto the real world in a way that does not recognise their representational nature – to attempt too close a fit is to render them useless.

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This section has thus far argued that the representation of scientific progress through metaphors of exploration strengthens the opposition between the new physics and classical physics, and that map metaphors reinforce the suggestion that the new physics asserts the impossibility of a complete knowledge of the world. Both are seen as part of the anti-deterministic argument. I would like to end this section by moving away from metaphors of exploration and examining a further way in which representations of scientific progress in the popular science books under scrutiny support their non-deterministic arguments.

I noted earlier that representations of revolutionary moments in science are often characterised by an emphasis on eureka moments, or moments of spontaneous insight. They are often also coupled with a strong sense of the role of contingency, of accident or chance, in the events that bring about a scientific revolution. Zukav, for example, stresses that "Planck did not intend to undermine the foundations of Newtonian physics [...] he inadvertently fathered the revolution of quantum mechanics" (*Wu Li*, 73). Greene concurs that "Planck had no justification for his pivotal introduction of lumpy energy" (*Elegant Universe*, 94) and that he just "made an inspired

[42] Jorge Luis Borges, 'On Exactitude in Science' in *Collected Fictions*, trans. by Andrew Hurley (London: Penguin, 1999), p. 325.

guess" (*Elegant Universe*, 91), and I have already mentioned Einstein's "happy day in the Bern patent office" (*Elegant Universe*, 60). This element of chance in representations of scientific practice is particularly prevalent, it will be noticed, in those moments in the history of science that are portrayed as critical, or revolutionary. This same contingency is emphasised not only in theoretical conjecture but also in scientific practice. Introducing Davisson and Germer's experiment that verified de Broglie's hypothesis of matter waves Zukav gives us scant information: what we are told is that "Both Davisson and de Broglie got Nobel Prizes", emphasising the importance of the work, and that "The famous Davisson-Germer experiment [...] was done by accident" (*Wu Li*, 119). Zukav does not elaborate on what chance element played such an important role.

This contingent narrative of scientific progress has been superbly parodied by Douglas Adams in his account of the development of an "Infinite Improbability Drive", which scientists had "grumpily announced [...] was virtually impossible"

> Then, one day, a student who had been left to sweep up the lab [...] found himself reasoning this way:
>
> If, he thought to himself, such a machine is a virtual impossibility, then it must logically be a finite improbability. So all I have to do in order to make one is to work out exactly how improbable it is, feed that figure into the finite improbability generator, give it a fresh cup of really hot tea [a Brownian Motion producer]... and turn it on!
>
> He did this, and was rather startled to discover that he had managed to create the long sought after golden Infinite Improbability generator out of thin air.[43]

This description is surprisingly closely paralleled by one from Gleick's *Chaos,* of Lorenz's experiments with weather simulation. Lorenz had been feeding weather patterns into a computer model, when

> One day in the winter of 1961 [...] Lorenz took a shortcut. Instead of starting the whole run over, he started midway through [...] Then he walked down the hall to get away from the noise and drink a cup of coffee. When he returned an hour later he saw something unexpected, something that planted the seed for a new science.[44]

Chance and intuition continue to play a part as the story unfolds. Gleick tells us how Lorenz "suddenly [...] realised the truth", and that he "could have assumed something was wrong with his particular machine – probably *should* have assumed [...] But for reasons of mathematical

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43 Douglas Adams, *The Hitchhiker's Guide to the Galaxy* (London: Gollancz, 2002), p. 68.

44 Gleick, p. 16.

intuition [...] Lorenz felt a jolt: something was philosophically out of joint".[45] Gleick sums up, rather dramatically,

> Lorenz's discovery was an accident, one more in a line stretching back to Archimedes and his bathtub. Lorenz never was the type to shout *Eureka*. Serendipity merely led him to a place he had been all along.[46]

Besides reasserting the importance of accident, the comparison with Archimedes does several things. Firstly, it places Lorenz's discovery into a pantheon of science; secondly, it suggests that contingency plays a role in discoveries in all the sciences; finally, the comparison either suggests the authenticity of the story of the bathtub, or, more likely, suggest that Gleick's version of Lorenz's day in 1961 may verge on the apocryphal.

The significance to my argument of the role of contingency should be immediately apparent. In chance occurrences within experimental science, accidents suggest the importance of the undetermined, of those elements that cannot be predicted, controlled or even fully understood by the experimenters and thus loosely mimic on a macroscopic scale the supposedly non-deterministic events taking place on a quantum scale. In this sense, chance is strongly associated with the level of irreducible uncertainty in quantum mechanics, with that element of "pure chance" (*Wu Li*, 92) that determines certain outcomes on a quantum level. The same is true of those theoretical speculations presented as part of the contingency of scientific progress; but there is the additional suggestion of the non-determinism of consciousness, since it is this inexplicable insight that, it is suggested, gives rise to these new, revolutionary theories.

3.3 Uncertain Shadows

Attempting to describe James Terrell's rotation effect, Zukav wastes no time in calling upon the analogy of Plato's cave. In order for the ensuing discussion to make sense, I digress for a moment to attempt an explanation of Terrell rotation that is non-mathematical but, whilst certainly drier, hopefully more precise than that of Zukav. Terrell's mathematical demonstration of the effect on the projected image of objects moving at near-light velocities shows that the object appears to rotate, rather than contract. In other words, although Lorentz contractions are measurable, we could never photograph them because at velocities approaching light speed the finite speed of the light travelling to the camera (or indeed our eyes) becomes significant. Imagine

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45 Gleick, p. 16, p. 17.
46 Gleick, p. 21.

a cube travelling across our line of vision from right to left at near-light speed. Because of the finite speed of light, light takes longer to reach us from the furthest corner than from the nearest corner. Thus light from this furthest corner that reaches us at the same time as light from a nearer edge must have left the object earlier, which consequently also means further to the right (a point earlier in time means a point earlier in the trajectory of the object). We therefore see both the furthest corner and the nearest corner of this edge perpendicular to the line of motion (and the same effect extrapolated to all points along this edge) – thus this edge is flattened towards us. When applied to all the light leaving the object the object appears rotated. Penrose showed that the rotation is in proportion to the Lorentz flattening and that therefore a sphere, for example, will always appear a sphere no matter which frame of reference it is viewed from.

I hope to show that the comparison between Terrell rotation and Plato's cave is a flawed analogy. But this is not simply an idle criticism – after all, flaws are relatively easy to uncover when enough pressure is applied to almost any analogy. Rather, my analysis shows that the introduction of Plato's cave is part of a wider use of shadow metaphors that serves to reinforce the argument for non-determinism of these popular science books.

There is a simple sense in which Plato's cave is not an accurate analogy: Lorentz contractions are a measurable phenomenon, and in this sense are a "real" effect of near light speed motion; but the implication of the comparison with Plato's cave is that they are simply a visual illusion, and this implication is supported by a number of phrases: "a moving object appears to contract in the direction of motion"; "this phenomenon is something like a visual illusion"; "it is the projection that contracts". But Lorentz contractions are not an illusion – in fact, the opposite is true, they cannot be seen, but they *can* be measured. So what then, is the significance of Plato's cave, and why is it introduced? Zukav, having described Terrell rotation, sums up: "The equations in the special theory of relativity (the Lorentz transformations) which show a contraction due to motion describe these *projections*. (Is this beginning to sound like Plato's cave?)" However, the contractions are not projections, but real effects that occur because of relative frames of reference – from our frame of reference an object really does flatten, even though from its frame of reference it is we that are in motion, and therefore it is we that contract. For this reason, the analogy with Plato's cave seems to hang on the use of the word 'projection'.

In fact, the most accurate part of the analogy with Plato's cave is that which Zukav does not mention. Plato's idea that the forms (the real objects in the cave) can be comprehended with our mind alone, and not empirically observed, does map quite revealingly onto the fact that Lorentz contractions may be understood rationally, but not perceived (what we 'see' would be Terrell

rotation). In Zukav's version of the allegory he emphasises the philosopher who escapes and *sees* the real world; but, of course, Plato's parable is already an analogy, and the real objects represent forms "which can only be seen with the eye of the mind".[47]

Although I am wary of attributing to Zukav deliberate obfuscation in this passage, there does appear to be compelling evidence. Instead of emphasising this element of the comparison which does hold between relativistic effects and Plato's cave, the idea that is stressed is that Lorentz contractions "describe *projections*", which as I have shown, is not really the case. Terrell's paper, in which he describes the rotation that we would see in place of relativistic contraction is entitled 'The Invisibility of Lorentz Contraction', a title that would seem to challenge Zukav's description of Lorentz contraction as a projection, and thus also the relevance of the introduction of Plato's cave. It is therefore conspicuous that the endnote with which Zukav references Terrell's paper cites the journal in which the article first appeared, but does not give the title of the paper: "J. Terrell, *Physical Review*, 116, 1959, 1041." (*Wu Li*, p.336 n.6). Revealingly, endnotes citing other journal articles (including those from the same journal) do include titles: "David Finkelstein, "Past-Future Asymmetry of the Gravitational Field of a Point Particle," *Physical Review*, 110, 1958, 965." (*Wu Li*, p.336 n.4)[48]

What, then, is the purpose of Zukav's introduction of the allegory of the cave? It is, I believe, an example of the use of the shadow metaphor as part of the non-deterministic argument that I identify in these popular science books. In employing shadow metaphors in this way Zukav draws on a long cultural history in which "[f]rom Plato on, projected shadow has intermittently also had to appear in the role of bearer of imperfect knowledge of the object that projects it".[49] 'Imperfect' is precisely the way in which both writers wish to characterise our knowledge of a supposedly non-deterministic world as seen through the new physics.

When Capra notes that "it makes no sense to ask which is the 'real' length of an object, just as it makes no sense in our everyday life to ask for the real length of somebody's shadow" (*Tao*, 177) he utilises the image of the shadow ostensibly because the length of a shadow is variable. But this is probably a secondary feature of shadows compared with the more primary association that is their projected nature, an association clear in the sentence which follows: "The shadow is a

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47 Plato, *The Republic*, trans. by Benjamin Jowett (New York: Cosimo, 2008; this translation first published 1894), p. 175. This quotation actually comes the book preceding the allegory of the cave, but as Socrates says having finished his description of the cave, "This entire allegory [...] you may now append, dear Glaucon, to the previous argument [i.e. that of the Divided Line in Book VI]" (p. 179).

48 For further examples cf. p. 334 n. 2, p. 337 n. 2, p. 338 n. 21 and many others.

49 Michael Baxandall, *Shadows and Enlightenment* (New Haven: Yale University Press, 1995) p. 144.

projection of points in three-dimensional space on to a two-dimensional plane" (Ibid.). The essence of the projected nature of a shadow means that it gives us only a limited representation of the "real" object that is casting it, and the analogy implies that we likewise only have a limited understanding of the fluctuating lengths of objects due to relativistic effects. In the above example of Zukav's use of the allegory of the cave, the analogy does not hold – the Lorentz contractions are measurable, and because of the special theory of relativity, also calculable. But at first sight Capra's slightly more careful comparison between a shadow, whose length varies, and a (moving) object whose length (along its line of motion) also varies, appears a better one. A shadow, as Capra says, is a projection of a 3D object on to a 2D plane; likewise a moving object is "the projection of points in four-dimensional space-time on to three-dimensional space" (Ibid.). In both cases the addition of missing information appears to 'complete' the projection – if we know the relative positions of the projection, object and light source we can calculate the real length of an object from its shadow; similarly if we know its velocity we can calculate a moving object's real length (from our frame of reference), including Lorentz contraction. So far, so good.

However, under closer scrutiny the essence of shadows reveals itself: they do contain an *inherent* lack of information – an irreducible uncertainty. Even with the angle of the light source, and distance from the object, one dimension of the object is still unknowable from its shadow – its depth – and other details, such as its colour, also remain obscured. A shadow can give us no information concerning one of the dimensions of the original three-dimensional casting object, but Lorentz transformations allow us to ascertain precisely the contraction that is undergone by an object at velocities close to light-speed. In other words part of the connotative field of the image of the shadow is the lack of information that they contain about the original; a shadow can convey only "imperfect knowledge of the object that projects it".[50]

The paradigmatic example of "imperfect knowledge" as represented in the new physics is Heisenberg's uncertainty principle, and it is therefore unsurprising that it is in this context that Zukav again invokes the image of the shadow.

> Since electrons are so small, [...] the wavelength of ordinary light is much too long to "see" electrons, in the same way that long sea waves barely are influenced by a thin pole sticking out of the water.
>
> If we hold a strand of hair between a bright light and the wall, the hair casts no distinct shadow [...] To see something, we have to obstruct the light waves we are looking with [...] An electron is large enough, compared to the tiny wavelength of gamma rays to obstruct some of them: to make a shadow on the wall, as it were. (*Wu Li*, 133-4)

[50] Ibid.

Zukav's description is an explanation of the uncertainty principle: we cannot get a clear 'shadow' of an electron with light with as long a wavelength as visible light – in other words we cannot 'see' it, or ascertain its position. But using light with a shorter wavelength – say, gamma rays – gives a different problem: gamma rays have far greater energy, and therefore, although they accurately establish the position of the electron, they affect its momentum in an unpredictable way. This is a version of one of Heisenberg's explications of his principle, an attempt to describe how uncertainty is manifested even in empirical attempts to ascertain measurements of canonically conjugate variables.[51] However, the shadow in Zukav's description complicates matters, because even were we able to resolve a distinct "shadow on the wall, as it were" of an electron, this shadow, as we have already seen, implies imperfect knowledge of the object itself. By using the shadow metaphor, Zukav suggests a secondary layer of uncertainty to the uncertainty principle.

It could be objected that these passages, by using shadow metaphors in conjunction with descriptions of relativistic and quantum phenomena in a way that activates the connotations of imperfect knowledge or representation, simply reflect the inherent uncertainties involved with the new physics. But the implications of relativity, though counter-intuitive, are not of indeterminism or even uncertainty: the effects of relative motion on both space and time are precisely quantified by Einstein's theories. It is true that quantum mechanics does describe the irreducible imperfection in our knowledge of the universe: we can never know both the position and momentum of a single electron. However, the philosophical implications of quantum mechanics are far from resolved.

The idea of the new physics that is presented in many of these popular science books is of undermining determinism and necessitating an indeterministic interpretation of the world. I have shown how anthropomorphic metaphors form part of the strategy for asserting a connection between consciousness and the new physics, a connection that is presumed to undermine determinism. I have also revealed how metaphors of exploration and maps present a normative history of scientific discovery as well as a distorted image of scientific practice. The presentation of scientific progress implies the obsolescence of classical physics and its supposed determinism; moreover, scientific theory and practice, through the emphasis on the role of contingency, is presented as *itself* characterised by indeterminism. Finally, I have explained how metaphors of shadows draw on the cultural history of the shadow as an imperfect representation, suggesting the new physics' inherent uncertainty about the world as part of the argument that determinism has been undermined.

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[51] This is often called Heisenberg's microscope.

But this representation overstates the connection between the new physics and indeterminism. It is by no means certain that quantum mechanics requires us to jettison determinism: different interpretations of quantum mechanics give different conclusions.[52] Simplifying greatly, Schrödinger's wave function equation is, if we ignore the quantum measurement problem, generally considered deterministic; the Copenhagen interpretation, with its collapse of the wave function, is, by contrast, indeterministic; and David Bohm's alternative interpretation, proposed in 1952 – a *hidden variables* interpretation which utilises a 'guiding equation' – restores determinism to quantum mechanics. Carl Hoefer sums it up this way:

> QM [quantum mechanics] is widely thought to be a strongly non-deterministic theory. Popular belief (even among most physicists) holds that phenomena such as radioactive decay, photon emission and absorption, and many others are such that only a *probabilistic* description of them can be given. [...] At the microscopic level the world is ultimately mysterious and chancy.
>
> So goes the story; but like much popular wisdom, it is partly mistaken and/or misleading. Ironically, quantum mechanics is one of the best prospects for a genuinely deterministic theory in modern times! [...E]verything hinges on what interpretational and philosophical decisions one adopts.[53]

The popular wisdom may be mistaken but it is a representation of the new physics that has been, as I have shown, propagated by many of the popular science accounts. Turning in the next chapter to contemporary fiction, we will see that it is also a conception of physics that has exerted influence over contemporary fiction writers who have sought to incorporate the ideas of the new physics into their writing.

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52 Interestingly, nor is it really the case that determinism is a constant in Newtonian mechanical systems. See J.D. Norton, 'Causation as Folk Science' for an example of a system "fully in accord with Newtonian mechanics" which "harbour[s] uncaused events and ones for which the theory cannot even supply probabilities" (pp. 8-12).

53 Hoefer, (section 4.4 Quantum Mechanics).

4 The New Physics and Determinism in Contemporary British Fiction

As I have shown in the previous chapter, popular science writing on the new physics, and particularly that which deals with quantum mechanics, has chosen to depict the new physics as a fundamental rejection of Newtonian mechanics. As such, the new physics is seen as a radical new science which denies the total determinism famously articulated by Laplace. Regardless of whether this representation is accurate, it is clear that this has been an important part of the cultural reception and public perception of the new physics.[1] It is also a feature of the new physics that contemporary writers have embraced: contemporary fiction which reveals an awareness of the ideas of twentieth-century physics also frequently shows an interest in the way in which the use of metaphors and ideas from the new physics can be brought to bear on ideas about determinism.

I will begin by showing how, just as in the popular science writing, the changes in twentieth-century physics are used to undermine the idea of universal determinism. I will then look at the problems and opportunities that this anti-determinist stance poses for narrative and examine briefly one particular narrative that is often encountered in these fictions – that is, historical narrative. I will argue that these contemporary authors do far more than simply incorporate and utilise the ideas of twentieth-century physics that have received widespread popularization. Many of the novels and plays examined in this chapter can also be seen to be engaged in an epistemological critique. If, my argument posits, the popular science writing on the new physics adopts and strategically deploys particular metaphors in order to emphasise a particular ontological argument – that determinism is fatally undermined by the new physics – then contemporary fiction may be adopting this ontological position *as a metaphor* as part of its own *epistemological* argument: that science does not hold all the epistemic cards.

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1 This is true from the outset. Reporting on Einstein's theory of relativity in 1919 *The Times* led with "Revolution in Science – New Theory of the Universe – Newton's Ideas Overthrown". Quoted in Gregory and Miller, p. 28.

4.1 Resistance to Determinism: Character and Plotting

Before going on to show how some contemporary authors use references to the new physics to conduct an epistemological critique of a monistic scientific epistemology, I will begin by showing how they have used references to the new physics as part of a broader resistance to determinism in their novels and plays. Just as we have seen with popular science on the new physics, the immediate interpretation of the implications of the new physics (normally broadened to include statistical mechanics and thermodynamics, as well as relativity and quantum mechanics) is that several developments have called into question the idea of a 'clockwork' determined universe. Perhaps it is no surprise that this interpretation should appeal to fiction writers, since narrative, which is a fully determined world, is often attempting to feign its own indeterminacy. The reader is invited to believe that the events in the novel are subject to choice, to accident, to chance – whereas in fact they are predetermined by the author.

One of the common, and in some ways simplest, interpretations of the developments in physics is the problematising of cause-and-effect in these narratives. In Thomas Pynchon's *Gravity's Rainbow* (1973) the opposition between determinism and indeterminacy is played out partly through the opposition of two sets of characters. On the one hand are those in thrall to the idea of a deterministic universe, those like Pointsman, the behaviourist who with Pavlov believes that "the ideal [...] in science, is the true mechanical explanation [...] No effect without cause, and a clear chain of linkages"; on the other hand there are those like Roger Mexico, who realises that "there is a feeling about that cause and effect may have been taken as far as it can go [...] the next breakthrough may come when we have the courage to junk cause-and-effect entirely".[2] Slothrop, the novel's principal character, lurches along the spectrum between these two camps. According to Pynchon's definition, paranoia is the "onset, the leading edge of the discovery that *everything is connected*" (GR, 703/834; italics in original); Slothrop, then, begins the novel as a paranoiac – he is conscious of a proliferation of causality, and feels the control of determinism: "all in his life of what has looked free or random, is discovered to've been under some Control, all the time, the same as a fixed roulette wheel – where only destinations are important, attention is to long-term statistics, not individuals: and where the House always does, of course, keep turning a profit..." (*GR*, 209/249).

[2] Thomas Pynchon, *Gravity's Rainbow*, p. 89/104 (hereafter *GR*). Page numbers will be given in the text for two different editions: the first refers to the 1987 Penguin edition (the 1978 Viking paperback uses the same pagination), the second to the 2000 Vintage paperback.

The determinism that Slothrop feels here is analogous to the first challenge to the clockwork universe – the practical impossibility of computing the movement of an individual atom. What Slothrop feels is the probabilities of statistical mechanics. Not, in other words, total determinism, but a very close approximation. Statistical mechanics can compute, say, the pressure of a gas inside a cylinder, through a calculation of the average movement of molecules within that cylinder, but cannot predict or describe the movement of any individual molecule; this idea is ingeniously imagined in a scene from *The Crying of Lot 49* (1966) in which a can of shaving foam, propelled by the compressed gas inside it, bounces unpredictably and dangerously around a small enclosed bathroom.[3] This clever image scales up the processes that are taking place inside the can, making them observable, and turns the can itself into an analogue for the unpredictable molecule of gas inside the can. We can see this same pattern, of unpredictability on one scale, and apparent determinism on another, played out in the scheme of the novella's plot: on the one hand Oedipa's life is constantly affected by chance events, as she bounces around the USA trying to unravel the mysteries of the Trystero; on the other, the string of chance encounters can be seen in the end to lead towards a point – the 'crying' of the lot of stamps at the auction – the predetermined nature of which is signalled, before the book is even opened, in the title.

In *Gravity's Rainbow*, in the passage quoted above, Pynchon draws the parallel with a casino, which cannot prevent an individual from winning, but over the long run the odds are set such that 'the house always wins'. Slothrop feels that his life, apparently free, has actually been under the same probabilistic control – his individual actions may be free, but the long term destination is determined, is a statistical (if not quite a literal) certainty. In this regard he is much like Oedipa. Slothrop begins to resist this feeling of control, and the form of *Gravity's Rainbow* itself also enacts a resistance to deterministic causality. In *Gravity's Rainbow*, the reader, and even more so the critic, is presented with a profusion of connection, an abundance of information. But Pynchon sets the signal-to-noise ratio deliberately high. This has led critics to look for connections where there are none to find, as Robert Nadeau has observed: "Critics in growing numbers have driven themselves to distraction looking for logical connections which would allow for a rational explanation for this 'ambiguity' in the novel [...] The clues are everywhere, but there is again that gap in logical, linear connections which precludes closure"; this is also one of the reasons that Nadeau warns that "any critic who chooses to tackle all *Gravity's Rainbow* in one chapter is either terribly ambitious or very foolish or both".[4] But many critics have missed the broader point, that Pynchon does not merely turn the critic into a paranoid who sees connections everywhere, but

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3 Thomas Pynchon, *The Crying of Lot 49* (London: Vintage, 2000), pp. 23-24.
4 Nadeau, p. 146, p. 137.

that the abundance of connection undermines the very basis of narrative – it threatens our understanding of cause and effect.

Initially, though, the proliferation of connections simply bemuses the characters within the novel. To take the most obvious example, the number of explanations offered for the co-incidence between Slothrop's map of sexual conquests and the map of the rocket strikes is implausibly high: psychokinesis, telepathy, precognition, conditioning to auditory or possibly visual signals, or to some material (perhaps Impolex G) in the rocket itself. The unknown nature of Jamf's "stimulus x" allows for more speculation. The connections between Slothrop and the rocket are so strong that everyone in the novel, Slothrop included, is searching for an explanation, one that they presume is there to be discovered. But there is no solution to the coincidence – none of the characters find one, nor is there one buried in the plethora of clues Pynchon teasingly includes for the reader or critic to uncover. When the possibility is introduced that not all of the stars on Slothrop's map are genuine – that he might have fantasised some of them – even the validity of the evidence for a connection is undermined. To use a phrase that has resonance for many of the works examined in the chapter, "Some questions have no answers to find".[5]

The proliferation is intended precisely to undermine linear causal explanation: the chaos of life, encyclopaedically represented in this novel, precludes this sort of linear analysis, and every attempt to explain the world this way fails. Brigadier Pudding's study of the European balance of power, *Things that Can Happen in European Politics*, is an example in little. Pudding was "brought up to believe in a literal Chain of Command", in fact "newer geometries confuse him" – he is, in other words, a linear thinker. His historical study takes this same linear form: "'First [...] Ramsay MacDonald can die'. By the time he went through resulting [...] permutations [...] Ramsay MacDonald had died. 'Never make it [...] it's changing out from under me'" [*GR*, 77/90-91]. This strictly linear, causal form of analysis simply cannot account for the proliferation of information in the world.

It should be noted that Pynchon quite explicitly implicates the reader and critic in the same unreasonable desire for comforting causality as many of the characters exhibit. Critics have commented on one of the novel's direct narratorial interventions in which, addressing the reader directly, the narrator grudgingly concedes – "You will want cause and effect. All right." (GR, 663/786). But the significance is in the context: these words begin a new 'chapter', but they also immediately follow on from the phrase "there are things to hold on to...". These two phrases are

[5] Michael Frayn, *Copenhagen* (London: Methuen, 2000), p. 3. All subsequent references are to this edition and will be made in the text.

separated by the row of seven boxes (in lieu of asterisks) that signal a chapter break, but the ellipsis also implies their connection: cause-and-effect is one of the cornerstones of our perception of reality and also of our understanding of narrative – it is one of the 'things we hold on to'. In Pynchon's worlds and narratives, however, we are rarely permitted such comfort – and we are denied it at this moment in the narrative too. Promised cause-and-effect, we get very little – "Thanetz was washed overboard [...] he was rescued by a Polish undertaker in a rowboat", immediately followed by the explanation that this Pole was "out in the storm tonight to see if he can get struck by lightning" (Ibid.). And then there follow tangents on Benjamin Franklin, calculus, masonic groups and headgear – so it is with Pynchon.

Elsewhere, another brief glimpse of the narrator's own voice again comments on the opacity of narrative causality. Amidst Pirate Prentice's "second thoughts" about bringing Katje back to England, we can discern the subtle intrusion of the narrator's own, metafictive, voice: "Indeed, why did she [Katje] leave Schussstelle 3? We are never told why." (GR, 107/126) Although this could be Pirate's thoughts, that 'we' implies not just that Pirate does not know Katje's motivations, but that the reader does not either – and, as importantly, that Pynchon is not going to tell us. The reader is left in the dark.

4.2 "This is not science, this is story telling": Resistance to Determinism in Narrative Form

In addition to these explicit statements of the demise of cause-and-effect, resistance to determinism in these novels can also involve a resistance to, or a reworking of, traditional narrative form. After all, as H. Porter Abbott notes "narrative itself, simply by the way that it distributes events in an orderly consecutive fashion, very often gives the impression of a sequence of cause and effect".[6] For even if Roger Mexico and Leni Pökler may perceive causality to be uncertain, the narrative in which they exist remains a closed determinate system, with the author deciding the course of all events. But Pynchon does his best to construct narratives which, in the reading, feel causally underdetermined. The narratives are wildly unpredictable: sequences which are tending towards more traditional linear narrative are often disrupted by contingent interventions that take the narrative swerving away. The disruption that is caused by, say, the little figure who steals Slothrop's clothes while he lies with Katje, is not only felt by Slothrop but also

[6] H. Porter Abbott, *The Cambridge Introduction to Narrative*, 2nd Ed. (Cambridge: Cambridge University Press, 2008), p. 41.

by the reader, as the narrative that has begun with Katje is interrupted and we follow Slothrop down a completely different narrative path (*GR*, 198, 236).

Beyond these disruptions to our sense of normal narrative causality, various formal conceits, and forms of narrative experimentation, also attempt to reduce the determinism of the narrative system, or at least to de-emphasise it or hide it. One of the ways in which this may be done is by removing or altering the inherent teleological structure of narrative. In Martin Amis's *Time's Arrow*, in which time flows backwards, the formal conceit undermines the dependability of cause-and-effect, to the constant confusion of the narrator. The reader quickly learns to reorder events so that causality is restored, but for the narrator cause-and-effect remain problematic. He eventually learns that "things are created in the violence of fire", that we all have to "take it in the ass each morning" and so on, but even towards the end the narrator admits that "the world has stopped making sense again".[7] For the narrator, almost anything can appear to cause anything else: "High romance brings with it, or seems to bring with it (I'm getting more and more tentative about cause-and-effect) an expansion of my role here at AMS [the hospital]". There is humour in the resulting situations, opportunities that Amis does not pass up, but there are also important ramifications of the reversal. Firstly, the narrator is a passive observer of events, without any control over the body that he inhabits – Tod's body "won't take orders from this will of mine".[8] This exempts the narrator from the immorality of the body he inhabits, and thus exempts Amis from the problem of the immorality of his narrator. Secondly, it removes the need for moral comment on the central episode of the novel – the events in Auschwitz. By inverting causality – and also, crucially, by keeping his narrator out of the loop – the actions of the protagonist take on an altogether different appearance: the reader can comprehend and make their own moral judgements, but the narrator, unable to see the true order of events and consequences of Tod's actions, cannot come to the same conclusions. Amis's narrator is far from reticent in making moral judgements – later in the novel he is outraged that Tod always takes the largest bill from the collection bowl in church – but his judgements are in the wrong place, at the wrong time.

4.3 Resistance to Determinism: Indeterminate History

We have already seen how a rejection of determinism is enacted in the problematising of the link between cause-and-effect, both for characters within the narrative (what causes the connection

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7 Martin Amis, *Time's Arrow: or The Nature of the Offence* (Harmondsworth: Penguin, 1992), p. 51, p. 52, p. 157.

8 Amis, p. 13.

between Slothrop's map and that of the rocket strikes?), and for readers of the narrative (where is this narrative about to go next?). However, if in a non-deterministic world it is difficult to extrapolate from cause to effect, then the corollary is that we cannot confidently move back from the effect to the cause. For this reason, representations of the demise of scientific determinacy are often also linked to an uncertainty of history, or the difficulty in establishing historical events.

Tom Stoppard's play *Arcadia* enacts the difficulty in reconstructing the events of the past through the enthusiastic, but in the end erroneous, researches of the Byron scholar Bernard Nightingale. The action of the play takes place in a single room – a school room in fact, a fitting location for a play not just "of ideas" but also "*about* ideas [...and] the processes that generate them", as Burkhard Niederhoff remarks.[9] While the location is, at least on the face of it, stable, the play is set across two broad time periods, with the division between the two destabilized in the climax of the play.[10] Many of the themes of the play – sexual attraction, the Enlightenment and Romanticism, epistemology and the pursuit of knowledge, loss and grief – are doubled up in the discussions of classical mechanics, thermodynamics and chaos theory. Although many of the themes in the play also connect with each other (Stoppard loves to layer the connections) the images and ideas drawn from science form a central core of the play.

It is in the conversations in the nineteenth-century scenes between Thomasina – the "uncomplicated" thirteen year old girl, who is also, however, much "cleverer than her elders" – and Septimus Hodge, her tutor, that classical mechanics is introduced into the play.[11] In an early scene set in 1809 we hear the words of Laplace unknowingly paraphrased and prophesied by Thomasina (Laplace's formulation comes in 1814 in the introduction to his *Essai philosophique sur les probabilités*):

> **Thomasina:** If you could stop every atom in its position and direction, and if your mind could comprehend all the actions thus suspended, then if you were really, really good at algebra you could write the formula for all the future; and although nobody can be so clever as to do it, the formula must exist just as if one could.
>
> (*Arcadia*, 5)

While Thomasina objects to the determinism of Newton's system, and finally exposes its flaws, Septimus is a confident Newtonian, believing that "time needs must run backwards" (Ibid.):

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9 Burkhard Niederhoff, "'Fortuitous Wit': Dialogue and Epistemology in Tom Stoppard's *Arcadia*', *Connotations*, 11 (2001-2), 42-59 (p. 42).

10 Technically the play is set in three discrete periods: 1809, 1812, and unspecified present.

11 Tom Stoppard, *Arcadia* (London: Faber, 1993), p. 14. All subsequent references are to this edition and will be made in the text.

when asked by Thomasina "Do we believe nature is written in numbers?", Septimus replies "We do" (*Arcadia*, 37). Thomasina, on the other hand, instinctively realises the limitations of Newtonian mechanics: "why do your equations only describe the shapes of manufacture? [...] Armed thus God could only make a cabinet" (Ibid.). She also appears to understand the flaw in Newton's system, that time is not reversible as Septimus imagines, and that the reason is the dissipation of heat. Towards the end of the play, Septimus examines Thomasina's diagram and begins to understand; Valentine, simultaneously on stage as the separation of the two periods dissolves, explains that what she realised ahead of her time was

> that you can't run the film backwards. Heat was the first thing which didn't work that way. Not like Newton. A film of a pendulum, or a ball falling through the air – backwards, it looks the same [...] But with heat – friction – a ball breaking a window [...] You can put back the bits of glass but you can't collect up the heat of the smash. It's gone. (*Arcadia,* 93)

It is a conclusion, a realisation, that questions Newtonian mechanics as the complete description of the world, and Septimus's confidence in the clockwork universe. As Thomasina puts it:

> **Thomasina**: Well! Just as I said! Newton's machine which would knock our atoms from cradle to grave by the laws of motion is incomplete! Determinism leaves the road at every corner, as I knew all along, and the cause is very likely hidden in this gentleman's observation.12
> **Lady Croom:** Of what?
> **Thomasina:** The action of bodies in heat.
>
> (*Arcadia,* 83-4)

Here, in a characteristic Stoppard *double entendre*, is revealed the connection between the themes of sexual attraction and science – "the attraction Newton left out" (74) as Valentine puts it. This type of pun, one that causes the conversation to become misleading for the interlocutors – a style of conversation perhaps best described by Stoppard's stage direction from an earlier instance, "*(answering the wrong question)*" (11) – plays a part in creating what Heinz Antor has described as the "semantic entropy" of the dialogue.[13] I will return to look at the disagreements regarding the epistemological effect of misunderstandings in the dialogue in more detail later.

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12 The gentleman that she is referring to is Jean Baptiste Joseph Fourier (1768-1830) whose essay describing the propagation of heat in a solid body won the Grand Prize in Mathematics of the Institut de France in 1812.

13 Heinz Antor, 'The Arts, the Sciences, and the Making of Meaning: Tom Stoppard's Arcadia as a Post-Structuralist Play', *Anglia*, 116 (1998), 326-54 (p. 350).

Thomasina is able to describe fully her insight only after reading an essay by Joseph Fourier from 1812, and she pre-dates Clausius's first formulation of the Second Law of Thermodynamics by nearly forty years. Fourier's essay does not constitute a "natural contradiction of Sir Isaac Newton" or show that "the atoms do not go according to Newton" (*Arcadia,* 81), as Stoppard has Septimus claim, but it is part of the work on heat that led to the concept of entropy.[14] Thomasina, though, has instinctively appreciated the entropic nature of the world from the very beginning of the play:

> **Thomasina**: When you stir your rice pudding, Septimus, the spoonful of jam spreads itself round [...] But if you stir backwards, the jam will not come together again. Do you think this is odd?
> **Septimus**: No.
> **Thomasina**: Well, I do. You cannot stir things apart.
>
> (*Arcadia*, 4)

In an important parallel, the demise of classical mechanics is also echoed in the play by the demise of the previously classical garden at Sidley Park, torn up by Capability Brown, and now being redesigned by the "landskip architect" (3) Richard Noakes. Noakes's Improved Newcomen steam pump also links the two themes: it is partly responsible for Thomasina's insight regarding heat loss, and also responsible for draining the lake as part of the new picturesque style garden. Hannah Jarvis, the garden historian working on the Sidley gardens in the present, tells us that:

> There's an engraving of Sidley Park in 1730 that makes you want to weep [...] By 1760 everything had gone – the topiary, pools and terraces, fountains, an avenue of limes – the whole sublime geometry was ploughed under by Capability Brown [...] so that the fools could pretend they were living in God's countryside. And then Richard Noakes came in to bring God up to date. (*Arcadia,* 27)

Comparing the changes in the garden to the broader shift from Enlightenment to Romanticism, Hannah notes that the "history of the garden says it all, beautifully" (27); but the analogy with classical science is even more explicit in the play. The 'sublime geometry' Hannah refers to reminds us of Thomasina's objections: both gardens and science are seeing the demise of classical geometry. Thomasina complains that Newton's equations can only draw "commonplace geometry, as if the world of forms were nothing but arcs and angles [...] if there is an equation for a curve like a bell, there must be an equation for one like a bluebell, and if a bluebell, why not a

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[14] Prapassaree and Jeffrey Kramer make a similar observation: "the laws of thermodynamics do not deny the absolute nature of time and space, or the deterministic behaviour of particles in motion, or even the possibility of a Laplacian observer[; ...] Septimus' declaration [...] is a bit hyperbolic". Jeffrey Kramer and Prapassaree Kramer, 'Stoppard's *Arcadia*: Research, Time, Loss' in *Modern Drama*, 40 (1997), 1-10 (p. 4).

rose?" (37). Later she objects that "Mountains are not pyramids and trees are not cones. God must love gunnery and architecture if Euclid is his only geometry" (84). Noakes's plans for the garden "is all irregular" (12), as Brice puts it, and elsewhere Thomasina describes Noakes as the "Emperor of Irregularity" (85); in parallel Thomasina's own "truly wonderful new [mathematical] method", which anticipates chaos mathematics and rejects classical geometry, she calls the "New Geometry of Irregular Forms" (43). These ideas look forward to chaos theory, looking for order in the apparent disorder of nature, and the sort of analysis that Valentine is doing one hundred and eighty years later, but it also represents another part of the growing pressure on classical mechanics.

In the play, history turns out to be as difficult to comprehend as Valentine's grouse populations: "Too much noise. There's just too much bloody noise!" (*Arcadia*, 62). Noise, in the case of history, comes in the form of lost data, like the covers to letters, one of which Septimus "tosses [...] negligently aside" (4); or destroyed evidence, like the letters Septimus burns; or confusing additions to the data, like Thomasina's drawing of the hermit; or ambiguities, like the fact that the botanist Chater in the West Indies is also the poet Chater in England, or the ambiguity of Chater's inscription of Septimus's edition of *The Couch of Eros*. The result of this 'noise' is that Bernard is convinced that he can show that Byron killed Chater in a duel before leaving England, and wrote two savage reviews of Chater's poetry, while neither is in fact the case.

In Stoppard's meticulously plotted play, much of the comedy (aside from his customary witty linguistic play) comes from the disparity between the events depicted in the nineteenth-century scenes, and the attempts at reconstruction by Hannah and Bernard in the present. The audience is allowed to see not only that Hannah and Bernard are getting things wrong, but also why they are doing so. Even though, in the light of new evidence, Bernard does finally concede that Byron did not kill Ezra Chater in a duel, there are many details about which they remain mistaken, and Stoppard highlights wherever possible the ambiguity, indeed the treacherousness, of the documentary evidence that Hannah and Bernard rely on: the "only known likeness of the Sidley hermit [...] Drawn in by a later hand, of course" (*Arcadia*, 25), in Noakes's sketchbook, was actually an absent-minded doodle by Thomasina; similarly, the Fuseli study that Hannah supposes is of Byron, but is 'analysed' and shown not to be, turns out to indeed be of Byron; the game book notes that Byron shot a hare, evidence that Bernard takes as gospel – "as sure as he shot that hare" (89) – but Augustus says that Byron "claimed my hare, although my shot was the earlier" (79), to which evidence we could add Septimus's earlier observation that Byron "was never a sportsman" (13).

Bernard and Hannah rely on documents (like the game book and letters), but actually it is their guesses that are more accurate – including Bernard sarcastic "platonic letter" from Byron to Septimus ending "p.s. Burn this" (*Arcadia*, 57): such a letter (or at least similar) did exist, and is burned by Septimus before he has read it, noting "Now there's a thing – a letter from Lord Byron never to be read by a living soul" (71). This fictional letter might even have revealed the solution to a real historical puzzle – why Byron left England.

The problems that Bernard and Hannah face in recreating the events of the past are central to an interesting trend in the critical responses to *Arcadia*, and one I would like to spend some time examining: that is, the debate over the epistemological scepticism of the play especially but not exclusively in those studies that pay particular attention to the play's scientific themes. Heinz Antor reads the play, notwithstanding a number of hopeful passages, as broadly sceptical about the possibility of knowing: "No matter where we look in the play, we time and again come across a scepticism with regard to our attempts at understanding the world and an awareness of the precarious status of the patterns we create in order to explain what we perceive".[15] He sees the play as showing that we have entered an age in which "it has become much more difficult to map the world and in which any pattern or structure may at best only claim a temporary truth status, since in a decentred universe ultimate meaning has become ungraspable and has to be pursued anew all the time, without there being a realistic hope of arrival".[16] Antor also argues that this difficulty in grasping meaning has been transferred into the language of the play, such that "there is a noise in the sense of communication being hampered by such factors as polysemy or varying frames of reference that lead to a kind of semantic entropy".[17] The language of the play embodies the "vicissitudes of the creation and communication of meaning".[18] Anja Müller-Muth similarly argues that "knowledge and insight are unevenly distributed in the play", that any knowledge gained in the play is "in the external communicative system, i.e. among the audience, who has access to the different frames of reference", and finally that "several uncertainties still remain unresolved at the end of the play for both characters and audience".[19] On the basis of these facts, she too reads the play as sceptical.

Other critics have interpreted the epistemological position differently, seeing the play as affirming the possibility of knowledge. Although even the sceptics mentioned above acknowledge the

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15 Antor, p. 348.
16 Antor, p. 349.
17 Antor, p. 350.
18 Ibid.
19 Anja Müller-Muth, "'It's wanting to know that makes us matter": Scepticism or Affirmation in Tom Stoppard's *Arcadia*', *Connotations*, 12:2-3 (2002/2003), 281-91 (p. 286).

positive representation of the process of seeking knowledge – or as Hannah puts it in the play, that even though "It's all trivial [...] It's wanting to know that makes us matter" (*Arcadia*, 75) – critics such as Daniel Jernigan and Burkhard Niederhoff have gone further and seen the play as, in John Fleming's words, "an affirmation that [...] people can use their intellect and intuition to gain knowledge".[20] Niederhoff's pair of essays contend that "the epistemology of the play is not sceptical" – not "a fashionable claim", he notes.[21] His argument is that:

> the outcome of the research or detective plot [...] precludes scepticism. The researchers may be plunged in comparative uncertainty, lagging behind the audience, but eventually they succeed in catching up, in falsifying or verifying their theories. This plot contrasts Bernard's theory, which is wrong, with Hannah's theory, which is right, and both are proved to be so in the course of the play.[22]

A sceptical play, he claims, would also end on a sceptical note – but *Arcadia* ends with Hannah receiving the piece of proof that she thinks she needs to prove her theory.

Daniel Jernigan, in an essay that examines the role of science in both *Hapgood* and *Arcadia*, supposes that we might expect Stoppard to "create a work that is quantum mechanically dubious about the possibility of narrative explicability".[23] In fact, Jernigan claims, this assumption "proves to be incorrect, as much of Stoppard's investigation into these theories [quantum mechanics and chaos theory] seeks to normalize them according to a classical interpretation rather than to revel in their anti-epistemological implications".[24] Jernigan defines the Enlightenment epistemology as a commitment to "rationality as the means by which truth is discovered" and sees this attitude as portrayed "whenever it [the play] suggests that rationality might be able to assist Bernard and Hannah in their recovery of the past. In fact, such instances are numerous".[25]

The debate between those who see the play as epistemologically sceptical and those who see it as epistemologically affirming seems to me to fall into the trap of "an either/or model".[26] Just as Fleming shows that Hannah "embodies Stoppard's notion that classical and romantic

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20 John Fleming, *Stoppard's Theatre: Finding Order Amid Chaos* (Austin: University of Texas Press, 2001), p. 200.

21 Burkhard Niederhoff, 'Who Shot the Hare in Stoppard's *Arcadia*? A reply to Anja Müller-Muth', *Connotations*, 13:1-2 (2003/2004) 170-78 (p. 170).

22 Niederhoff, 'Fortuitous Wit', p. 55.

23 Daniel Jernigan, 'Tom Stoppard and "Postmodern Science": Normalizing radical Epistemologies in *Hapgood* and *Arcadia*' in *Comparative Drama*, 37 (2003), 3-35 (p. 3).

24 Jernigan, p. 4.

25 Jernigan, p. 23.

26 Fleming, p. 201.

temperaments are not mutually exclusive, but rather co-exist in people" sceptical and affirmative epistemological positions can coexist within the play: we need to use a "both/and paradigm".[27]

It is relatively easy to marshal evidence on both sides of this debate, and I do not want to come down too heavily on either side, precisely because I think that the play also deliberately avoids doing so. *Arcadia* is not so much interested in the possibility of establishing 'ultimate meaning', as in the means by which we go about searching for it – even, perhaps, while "knowing that failure is final" (*Arcadia*, 75 – the phrase concludes Hannah's 'It's all trivial' speech). But nor is this to say that Hannah simply speaks for the play when she argues that all knowledge is in itself 'trivial', but that "It's wanting to know that makes us matter" – or as Antor and others have put "it is the journey that matters, not the arrival".[28] I don't think that Stoppard's intended conclusion is so pat, indeed so trivial, as that. I *will* argue that the play's epistemology *is* sceptical in certain ways, but not in the way that Antor and Müller-Muth have claimed, and not in the way that a sceptical reading of the play is characterised by Jernigan or Niederhoff.

The interpretation of the play as being non-sceptical, as epistemologically affirming, seems to me to isolate details of the plotting and dialogue in a way that, while supporting the argument, is at odds with the general thrust of the play. It is possible to argue that the refinement of the theories of Hannah and Bernard over the course of the play suggests that the play is not sceptical about the possibility of knowledge and a broadly scientific methodology more particularly. Perhaps it is true too that some of the resolutions are not entirely sceptical. But to read the play this way seems to me to be a case of not seeing the wood for the trees. It is a problem that Richard Corballis diagnoses more broadly in audiences of Stoppard's plays, though he is remarking on the failure to appreciate the "essential substance of a play": "Like Donne surveying his mistress for the first time in the flesh in 'Air and Angels', they get dazzled by the surface effects [...] The surface brilliance inhibits appreciation of the underlying design".[29]

An analogy for such a reading – allowing a few details to overwhelm a broader emphasis, notwithstanding the truthfulness of those details – can be found in Noakes's garden. Noakes's plan for the garden "is all irregular" (12), as Brice puts it, and elsewhere Thomasina describes Noakes as the "Emperor of Irregularity" (85); but as Heinz Antor points out, "Noakes's garden, of course, is not chaotic at all, but well planned".[30] To emphasise, however, this planning at the expense of the manifest irregularity, would be ridiculous, even though true; and Antor does not

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27 Ibid.
28 Antor, p. 352, and quoted by Niederhoff, 'Fortuitous Wit', p. 56.
29 Richard Corballis, *Stoppard: The Mystery and the Clockwork* (Oxford: Amber Lane Press, 1984), p. 1.
30 Antor, p. 333.

do so, instead going on to note that the garden "nevertheless stresses discontinuities and nonlinearity rather than symmetry and cohesion".[31] In other words, the meticulously planned garden may still represent the chaotic. Likewise, a play with some narrative resolutions (e.g. that Hannah finds the proof that Septimus was the hermit), with some progress made in Hannah and Bernard's reconstruction of events, and with Thomasina and Septimus's development of a radical new mathematics, such a play can still emphasise the contingency and instability of knowledge.

The same may be said of the disagreement between Antor and Niederhoff over the 'semantic entropy' of the play's dialogue. Antor suggests that the movement towards increased disorder and entropy is also represented in the dialogue of the play, particularly in the misunderstandings created through puns or "varying frames of reference", as I noted earlier.[32] Niederhoff, on the other hand believes that it is "misleading to describe the misunderstandings of the play as 'semantic entropy'. Instead of disrupting or dissolving meaning, they create it".[33] Niederhoff rests his argument on three assertions: firstly, that the "sheer fun and ingenuity of the two passages quoted should preclude a description in terms of 'semantic entropy'"; secondly, that misunderstandings create connections between, say, sexuality and the garden, that are "crucial to the thematic structure of the play"; and finally, that misunderstandings in the first scene "lead to crucial discoveries on Thomasina's part [...] The interruptions to Thomasina's lesson do not cause pedagogical or cognitive entropy. They result in worthwhile lessons and insights".[34] I perceive flaws in all three contentions.

The first two assertions reveal an important distinction. The witty ingenuity and thematic connections evident in the word-play of *Arcadia* are a species of meaning created only for the audience of the play, not for the characters within the play. This is important for two reasons: firstly, that discussion of the epistemological attitude of the play must revolve around knowledge as it is sought and achieved *within* the diagesis – for the characters, not for the audience. This, of course, is sensible; an epistemological argument regarding the play that was based on an assessment of the ability of the audience to achieve knowledge would really be a measure of how comprehensible the play was. An incomprehensible play is, perhaps, one way in which a playwright could undermine or question the stability of knowledge and our pursuit of it, but it is not the method that is evidently chosen by Stoppard. The second reason is that the creation of meaning for the audience through disordered dialogue is synecdochic of the argument that I have been advancing: that the confusion that the play *depicts* is more indicative of the play's

31 Ibid.
32 Antor, p. 350.
33 Niederhoff, 'Fortuitous Wit', p. 44.
34 Niederhoff, 'Fortuitous Wit', p. 46, p. 47.

epistemology than the entertainingly ordered play that the audience watches. Both the dialogue and the events of *Arcadia* are comprehensible to the audience even at the same time as they are confusing for the characters (this is perhaps the very essence of farce): it is from this that much of the play's humour is derived, but the audience's understanding does not preclude the possibility of the play's taking an epistemologically sceptical position.

Niederhoff's final piece of evidence for the meaning creation of the misunderstandings in the dialogue (and, indeed, interruptions, slips of the tongue, and overhead phrases) is that Thomasina learns from them. This is true. (Müller-Muth's objection that Thomasina's "reactions to Septimus's evasive answers to her questions about carnal embrace very clearly indicate that she already knows what this expression means", and therefore does not learn this in this scene, is not, I think, convincing.)[35] Certainly Thomasina may well be seen as one of the only characters who does achieve knowledge in a way that could be epistemologically affirming. But she does not, I think, achieve this knowledge predominantly from the confusions and misunderstandings in the conversations between characters. It is revealing to consider what exactly Thomasina learns from the confusions of the opening scene – Niederhoff provides a list: "She learns what carnal embrace is, that it addles the brain, that Septimus shared it with Mrs Chater, and that Septimus is in love with her mother; [...] she also has a first inkling of the second law of thermodynamics or the principle of entropy".[36] Once we realise that the last in this list is inadmissible as evidence (Thomasina simply has her idea about rice pudding because that is what is for dinner, not because of any semantic confusion) the pattern emerges easily: Thomasina learns about sex and sexual attraction. Given the connection that the play establishes between sexual attraction and the non-rational, the Romantic, the disorderly, and the non-deterministic, it should come as no surprise that Thomasina's knowledge of it comes about through the semantic confusion in this scene.

In a footnote to her essay Anja Müller-Muth notes that the use of the phrase 'semantic entropy' is itself "rather inappropriate for this context" since it denotes words that are drained of meaning due to repetition or, to use a fitting word, reiteration, rather than due to multiple meanings. She does not note that this in some ways supports the argument that she is trying to refute, that the dialogue contains not a lack of meaning, but a superfluousness of meaning.[37] Of course, to inject the play with genuine semantic entropy in the dialogue would be to write a play deliberately populated with banalities and clichés (certain scenes from Beckett spring to mind), not a very

35 Müller-Muth, p. 283.
36 Niederhoff, 'Fortuitous Wit', p. 48.
37 Müller-Muth, p. 288.

Stoppardian approach. In attempting to represent disorder, Stoppard does not allow the play itself to descend into confusion. Stoppard is content to work within the constraints of a kind of realism or at least orderliness, while trying to also reveal the disorderliness of reality. As Stoppard himself notes, he wants to retain a sense of narrative: "I want to [...] organize this impossible Rubik's Cube, so that it still has the architecture of a – what is the word? – not *conventional*, not *traditional*, but somehow atavistic archetypal architecture of narrative".[38] Lucy Melbourne makes the comparison with a phrase from Thomasina: "Stoppard might well declare his intent for a new 'drama of irregular forms'".[39]

Stoppard, then, creates dialogue that is representative of entropy without being itself devoid of meaning – in fact, it often bristles with many meanings – but it does represent the difficulties in establishing meaning, it represents the noise inherent in communication, and as such the difficulties in transmitting knowledge. There is one passage in particular that I think strongly supports an anti-epistemological interpretation of the dialogue of the play, one that has received scant attention, and yet which seems to speak to many of the play's themes.

When Septimus deviously sets Thomasina a passage from *Antony and Cleopatra* translated into Latin as a translation task to be translated back into English, we are presented with a genuine example of 'semantic entropy' – indeed the phrase derives precisely from translation theory. Here, the impoverishment of Thomasina's version of the speech, the draining of its meaning, is due to the reiteration: the new 'Latin' text is used as the starting point for the subsequent transformation. This is a 'rabbit' translation to go with Thomasina's 'rabbit' equation: "it eats its own progeny" (*Arcadia*, 77). As a consequence the instability of language is clear – the permutations of language are too vast to return to the original by simply performing the same action in reverse. Instantaneously this idea recalls not only the sensitive dependence on initial conditions of an iterated algorithm that is familiar to us from chaos theory, but also the irreversibility of certain processes, as the Second Law of Thermodynamics reveals about time. It is surely no coincidence that the speech that Stoppard has Septimus have Thomasina translate is one which itself embodies the paradox of representation through language. In Septimus's own "free translation" (*Arcadia*, 37) he ends with the crucial phrase: "For her own person, it beggared all description – she did lie in her pavilion – " but the speech continues

> For her own person,
> It beggared all description. She did lie

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38 Quoted in Lucy Melbourne, "'Plotting the Apple of Knowledge": Tom Stoppard's *Arcadia* as Iterated Theatrical Algorithm', *Modern Drama*, 41 (1998) 557-72 (p. 563).

39 Melbourne, p. 563.

> In her pavilion—cloth of gold, of tissue—
> O'er-picturing that Venus where we see
> The fancy outwork nature.[40]

Language is too impoverished to describe Cleopatra, and yet Enobarbus continues to attempt to utilise it.

This episode also foreshadows Hannah's later observation about the purpose of pursuing knowledge: she does not want the answers to be "in the back of the book" because the joy of knowledge is in the discovery. For Thomasina, the frustration of Septimus's trick is that the answer is in a book – and that there is a right answer, there is a true translation. The process becomes, in her eyes, frustrating and pointless because the translation has already been done; but, ironically, the scene also confirms that the point of 'work', of seeking knowledge, is the process. Thomasina doesn't do the translation in order to produce a translation, but for the benefits of going through the process.

I claimed above that isolating certain details to argue for the epistemologically affirmative nature of the play was to not see the woods for the trees. The same kind of reading could also be used to assert the scepticism of the play, and would be equally flawed. There is some argument over the degree to which, say, Hannah's theory that Septimus is the hermit can be said to be 'proved' correct at the close of the play, but two mysteries do remain unquestionably unsolved at the play's end: the reason for Byron's departure from England and the proof for Fermat's theorem. The fact that the play does not solve these puzzles is not evidence that the play takes an anti-epistemological stance, since these are real-world problems that remain unsolved (or remained unsolved at the time of the play's composition in the case of Fermat's theorem). Readings of the play that take this sort of approach are guilty of precisely the scholarly approach of which Hannah accuses Bernard: "You've left out everything that doesn't fit" (*Arcadia*, 59).

However, the play does draw considerable attention to these remaining uncertainties: the fact that a solution to Fermat's theorem "has kept people busy for a hundred and fifty years" (*Arcadia*, 2) is amplified by the knowledge that the audience already has (or will learn during the course of the play), that it continued to do so for a further two hundred years; and just as with Fermat, the fact that no one knows why Byron leaves England is equally apparent in both time periods, and the only possible source for a solution (aside from Byron, who remains off-stage) is a letter that Septimus conspicuously burns on stage, musing "Now there's a thing – a letter from Lord Byron

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40 William Shakespeare, *Anthony and Cleopatra*, Act 2, Sc. 2, ll. 204-208 in *The Complete Works*, Compact Edition, ed. by Stanley Well and Gary Taylor (Oxford: Clarendon Press, 1994), p. 1010.

never to be read by a living soul" (*Arcadia*, 71). It is the fact that the play so deliberately brings these unsolved mysteries to our attention, rather than the fact that it leaves them unsolved, that does support the play's own particular epistemology. And this is the point – the play is not simply sceptical, or not: it doesn't just depict the possibility of reaching knowledge via rational means, nor does it simply reject this; it doesn't normalize the supposedly radical epistemology of chaos theory into a classical rational epistemology (à la Jernigan), nor does it put forward a genuinely anti-epistemological argument "reveling in the fact that knowability is an impossibility".[41] Rather, it presents its own epistemology.

When Thomasina says that Fermat's last theorem is a problem without a solution, that it is just there to drive us mad, she recalls a similar observation by Niels Bohr in Michael Frayn's play *Copenhagen* that "Some questions have no answers to find" (*Copenhagen*, 3). Just as we cannot be "really really good at algebra" (the one fictional interpolation into Thomasina's speech – it is otherwise near-verbatim Laplace), so we cannot solve all problems. This points to the play's emphasis on the *limits* of a scientific epistemology, not of its complete invalidity. The same limitation, though, is placed on the humanities too – and Stoppard has noted that Bernard's rant against science is not his own position. If these traditional forms of knowledge are shown to be limited, then at the same time an importance is attached to alternative forms, such as intuition, in the form of Gus's inexplicable interventions, or interpersonal and sexual dynamics – these too are suggestive of a limit on the completeness of rationalism as an epistemological system. The play, then, enacts the insufficiency of any single monocular epistemology.

Just as in *Arcadia*, Michael Frayn's *Copenhagen* dramatizes the difficulties in attaining knowledge, asking, indeed, the "further question, whether under any conditions penetration to a single truth embedded in a determinate reality can be achieved", and just as in *Arcadia*, this is linked to the impossibility of reconstructing history.[42] Like *Arcadia* too, this coincides with an elaboration of a post-Newtonian non-deterministic science, in this case the Copenhagen Interpretation of quantum mechanics, and Heisenberg's uncertainty (more properly, indeterminacy) principle in particular. The play focuses on a visit that Werner Heisenberg made in 1941 to his former colleague and close friend and mentor Niels Bohr in Nazi-occupied Copenhagen. The reasons for Heisenberg's visit, and exactly what was said between the two men, have been the subject of speculation and controversy ever since. In Frayn's play, first performed in 1998, these uncertainties are discussed by the ghosts of Heisenberg, Bohr and Bohr's wife Margrethe as they

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41 Jernigan, p. 32, n. 4.

42 Martin Meisel, *How Plays Work: Reading and Performance* (Oxford: Oxford University Press, 2007), p. 145.

make "one more attempt" to understand the conversation that led to "the end of the famous friendship between Niels Bohr and Werner Heisenberg" (*Copenhagen*, 4).

The play is in two acts but, in imitation of the multiple drafts of a physics paper, is structurally divided into three 'drafts', three attempts to establish precisely what took place during Heisenberg's visit, what was said by both men, and what Heisenberg's motivations for coming to Copenhagen were.[43] A number of concepts from the Copenhagen Interpretation of quantum mechanics make appearances in the play, but it is Heisenberg's uncertainty principle that is most conspicuous. All critical interpretations of the play have identified the unmissable connection that Frayn makes between Heisenberg's uncertainty principle and the uncertainty that is attached to reconstructing the events and motivations of Heisenberg's visit. The uncertainty principle shows that there is a necessary limit to our possible knowledge of the subatomic realm: we cannot ever know precisely both the position and the momentum of a subatomic particle, and the relationship between our knowledge of the two variables is inversely related – in other words, the more precisely we know the position of the particle, the less we know about its momentum, and vice versa.[44] The principle is often wrongly described as an 'observer effect' – that we cannot observe something without affecting it – but this is a simplification. In fact there is a precise ratio of precision between our measurement of canonically conjugate variables such as position and momentum.

In the aftermath of *Copenhagen*'s premiere in London in May 1998, and even more so after its United States premiere in New York in April 2000, the play was subject to considerable criticism. The initial criticisms, following the London premiere, focussed on inaccuracies in what Frayn has called his "shaky science", and Frayn made a "number of modifications" before the play opened in New York.[45] In the wake of the US premiere, however, the play was criticised far more broadly, and particularly for perceived historical inaccuracies, and for its apparently overly sympathetic depiction of Werner Heisenberg. Michael Frayn responded to many of these criticisms in his post-postscript written for the third edition published by Methuen in 2003, but subsequent commentary has continued to focus on the historical accuracy of the play. Such a focus is justified, according to Gerald Holten, one of the more vocal critics of the play, because Frayn's own post-scripts have shown that "he is not satisfied to have *Copenhagen* be and remain a

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43 Bohr in particular was renowned for his almost obsessive redrafting of papers.

44 In fact, to be precise, the same effect is true of our observations of particles and bodies on all scales, only that the margin of error in our measurements of momentum and position for bodies larger than the microscopic scale is so disproportionally small as to be unnoticeable. On a subatomic scale, however, the uncertainty is significant.

45 Michael Frayn, 'Friends and Mortal Enemies', *Guardian*, 23 March 2002, *Saturday Review* <http://www.guardian.co.uk/Archive/Article/0,4273,4379725,00.html> [accessed 3 April 2009].

work of fiction".[46] Steven Barfield likewise suggests that the reaction to the historical arguments in the play were precipitated not by the play itself, but by Frayn's own desire to separate the fictional from the historical. "In this Postscript," Barfield claims, "Frayn has suggested that the play is some kind of historical account".[47]

Regardless of whether it is valid to level these criticisms at the play, one of the inevitable consequences is that many critics have lost sight of the mechanics of the play as a play; more significant than whether their historically focussed criticisms are invalidated by the fictional nature of the piece *per se* is that their failure to read the play as fiction leads them into specific criticisms which are misreadings. Frequently, the problem is simply conflating the words of the on-stage Heisenberg with the opinions and intentions of the playwright.[48]

At its most extreme this can lead to some strange accusations. Commenting on the scene in which Heisenberg notes the irony – the "something almost mathematically elegant" – about the fact that the diffusion calculation was done by Jewish exiles from Germany, Paul Lawrence Rose identifies an "implicit anti-Semitism".[49] However, he shies away from attributing this to Michael Frayn: "not of Mr. Frayn himself, of course, but of Heisenberg and others".[50] But what exactly is Rose proposing here? That the fictitious character Heisenberg on stage is anti-Semitic, or that because of this comment in this play, the historical Heisenberg was anti-Semitic? In the context of his argument (a historical, not a literary one) the first conclusion seems banal, the second absurd. If not to Frayn, then to whom is Rose really referring? And who are the "others" that he also accuses? Regardless of whether or not this exchange implies any anti-Semitism at all (rather, I think it obviously alludes to the ironic problem that Nazi anti-Semitism has created for itself by forcing such scientists into exile), the problem Rose faces is deciding who he thinks is speaking here: a character, a historical figure, or a playwright.

We can take this issue further. In writing the play, Frayn was heavily influenced by Thomas Powers's book *Heisenberg's War*. Powers argues that Heisenberg had done the diffusion equation but misled Nazi authorities – especially Speers – about the amount of fissionable material that

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46 Gerald Holten, Jonathan Logan, Michael Frayn and Thomas Powers, '*Copenhagen*: An Exchange', *New York Review of Books*, 11 April 2002 <http://www.nybooks.com/articles/15264> [accessed 23 March 2009].

47 Barfield, Steven. 'Dark matter: The controversy surrounding Michael Frayn's *Copenhagen*', *Archipelago*, 8.3 (2004), 80-103 (p. 84).

48 Similarly simplistic, if tempting, conflations have also led to misinterpretation of the role of scientific rationalism in the novels of Ian McEwan, as I will show in chapter 6.

49 Paul Lawrence Rose and Thomas Powers (reply), 'Copenhagen Cont'd.', *The New York Review of Books*, 9 May 2002 <http://www.nybooks.com/articles/15373> [accessed 23 March 2009].

50 Ibid.

would be required, in order to discourage significant investment in the bomb development programme. One of the accusations that has been levelled at Frayn is that while *Copenhagen* seems to adopt this argument (what might be described as the 'strong' Powers thesis), in subsequent post-scripts and interviews Frayn retreated from this position to the 'weaker' thesis, namely that Heisenberg and the other German scientists lacked the total commitment that would have been required to make the project successful.[51] Holten, for example, has followed this line of criticism, and has wondered as a result how this retreat affects the play, asking:

> what to do about such lines in his play as "Heisenberg's" dramatic remarks: "I understood very clearly. I simply didn't tell the others"? And later: "*I* wasn't trying to build a bomb. Thank you." Perhaps should the actor now deliver the lines with heavy irony?[52]

Regardless of whether the initial accusation itself is justified,[53] this comment, which at least focuses on the play and shows an awareness of the presence of an actor and of delivery, misses a crucial point – the character Heisenberg does not express Frayn's thesis (if such a thing exists) in the same way that Powers's book can be said to express his. Barfield cites the example of Gerald Logan, who misreads the 'strange new quantum ethics' episode that I shall examine later, noting that "Logan's criticism is therefore problematic, because he does not recognise the critical strategies necessary for reading the words of a character in a play, but assumes the whole piece should be read, as if it possessed the coherency of a thesis".[54] Once we appreciate this it is hardly surprising that this fictitious Heisenberg should defend some of his actions, and that as a playwright Frayn should also try to "make explicit the ideas and feelings that never quite get expressed in the confusing onrush of life".[55] In his post-post-script Frayn records his belief that "everyone [in a play] should be allowed the freedom and eloquence to make the most convincing case that he can for himself".[56] The conclusion that we should draw from this is that Heisenberg's words are not Frayn's message; if we are determined to isolate a 'message' for the play, then it must come from a more holistic (this is not a great deal to ask) appreciation of the dialogue of all the characters in combination with all the dramaturgical apparatus.

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51 Duncan Wu, 'Michael Frayn, *Copenhagen* (1998)', in *Making Plays: Interviews with Contemporary British Dramatists and Directors*, ed. by Duncan Wu (Basingstoke: Macmillan 2000), pp. 209-230 (p. 224).

52 Holten, Logan, Frayn and Powers <http://www.nybooks.com/articles/15264> [accessed 23 March 2009].

53 I personally do not believe it is. Firstly for the reasons stated below, that the character Heisenberg may present a version of the strong Powers thesis in defence of himself, but this does not necessarily mean that Frayn does so; but more simply, Frayn quite clearly puts forward his belief in the weaker version in his interview with Duncan Wu in March 1999, long before the criticisms that followed the US premiere. (Wu, p. 219)

54 Barfield, p. 90.

55 Michael Frayn, *Stage Directions: Writing on Theatre 1970-2008* (London: Faber, 2008), p. 78.

56 Ibid.

One of the realisations resultant from such a conclusion is the almost complete lack of attention that has been paid to the vital role of Margrethe in the play. Discussion has tended to circle around the dialogue between Bohr and Heisenberg, and the subsequent non-dramatic writings of Frayn; but Margrethe's character acts as an important corrective to Heisenberg's claims and to both Bohr and Heisenberg's romantisization of their relationship, and as such is a crucial part of the play's representation. Barfield, one of the exceptions, observes that:

> The character of Margrethe [...] is sceptical throughout *Copenhagen* of Heisenberg's claims, and her attitude is closest to that of historians such as Rose and Holton. She undermines exactly the kind of arguments on behalf of Heisenberg that someone like Thomas Powers makes. The fictitious 'Heisenberg' that Frayn creates, lies closer to Power's account, because that book is much more favourable to the way that the real Heisenberg presented himself and his actions, in his own comments. *Copenhagen*'s Heisenberg couldn't represent himself in the same way that Rose's interpretation of Heisenberg does, because people are seldom so hostile to themselves.[57]

The following exchange, an excellent example of Margrethe's function and also of the way in which the play distances itself from Heisenberg's claims, reveals the dangers of removing Heisenberg's statements from the context of the play:

H: I understood very clearly [how to build the bomb]. I just didn't tell the others.
M: Ah.
H: I understood, though.
M: But secretly.

(*Copenhagen*, 80)

Margrethe's responses here make it quite clear that she is mocking Heisenberg and is deeply sceptical of his claims. Margrethe's role as an observer also highlights the similarities between the problems of scientific and historical observations. Without the effect of observers, the play implies, we might be able to ascertain what actually happened:

B: Very well. Let's start all over again from the beginning. No Gestapo in the shadows this time. No British intelligence office. No one watching us at all.
M: Only me.
B: Only Margrethe.

(*Copenhagen*, 38)

[57] Barfield, pp. 86-7.

Margrethe's presence reminds us that an observer-less system cannot exist: that even if there is a determinate truth in order to describe what happened there needs to be someone to explain it to. There is also a comic irony on a metadramatic level, in Bohr's claim that they can start again, with "No one watching", because it reminds us of our own observation of the process: the audience is made complicit in the impossibility of reconstructing the meeting. This complicity was emphasised by the design of the original production. The play was set in the round, and the

> now-famous set was a circular playing area surrounded on one side by three rows of curved seating arranged like a lecture theatre or a jury bank. This led Harry Lustig and Kirsten Shepherd-Barr to view the actors as particles within an atom and the setup of the audience as a way of emphasizing the theme of observation, with spectators watching other spectators watching the performers.[58]

The play's metadramatic awareness indicates that we should also follow Barnett in recalling (as few have) that the mechanics of the play's setting and construction are overtly anti-realistic – this is not a realist representation of the events, but an after-death recollection of them. It is perfectly possible to imagine a version of the play that still included the three 'drafts', but re-enacted them as alternate realities. But this is not the play with which we are presented. Rather, the characters discuss the events that took place from the perspective of an unspecified afterlife. This, Barnett has argued, "emphasizes the artifice of the situation" and alerts the audience to the fact that:

> the play is not dealing in anything but imagined encounters [...] This position helps to expose the apparently naturalistic dialogues for what they are: constructions born of those involved and not an objective history, as if such a thing were ever possible.[59]

Although, as we will see, the play utilises an at times fluid temporal perspective, the predominant mode is a retrospective examination of the events of 1941, opening with a series of questions which characterises the play's uncertainty: "But why? [...] You're still thinking about it? [...] Why did he come to Copenhagen? [...] Does it matter, my love, now we're all three of us dead and gone?". But also made clear here, in the "still [...] now [...] dead and gone", is the temporal location of the characters. The play soon shifts, however, back to the 'present' of 1941:

> **H:** September, 1941, Copenhagen... And at once – here I am, getting off the night train from Berlin with my colleague Carl von Weizsäcker.
>
> (*Copenhagen*, 6)

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58 David Barnett, 'Reading and Performing Uncertainty: Michael Frayn's *Copenhagen* and the Postdramatic Theatre', *Theatre Research International*, 30 (2005), 139-49 (p. 146).

59 Barnett, p. 142.

Here, in the play's first change of temporal location, the shift is amply signalled – firstly, by Margrethe, who comments that "The past become present inside your head", and also by the reminder of the date and location, which acts a little like an on screen caption in a film. The shift is also facilitated by the unspecified tense leading in to Heisenberg's 'arrival' in 1941. Elsewhere, however, the shifts in tense are more rapid:

> **M:** Niels! They've occupied our country
> **B:** He is not they.
> **M:** He's one of them.
> **H:** First of all there's an official visit to Bohr's workplace [...] At the head of the table is that Bohr? [...] A difficult occasion, though – I remember that clearly enough.
> **B:** It was a disaster. He made a very bad impression. Occupation of Denmark unfortunate. Occupation of Poland, however, perfectly acceptable. Germany now certain to win the war.
> **H:** Our tanks are almost at Moscow. What can stop us? Well, one thing, perhaps. One thing.
>
> (*Copenhagen*, 7-8)

Here the perspective shifts, very briefly, from the present of 1941 to the later perspective, reminding both the audience, and Heisenberg, of the dramatic irony of his confidence in Germany's victory. It also reminds Heisenberg of the 'one thing' that could prevent a victorious Germany.

These dramatic ironical gaps that the shifting temporal perspective can open up are even more conspicuous elsewhere. So it is that Bohr can, rather patronisingly, tell Margrethe that "Heisenberg is a theoretical physicist. I don't think anyone has yet discovered a way you can use theoretical physics to kill people", and that "no one is going to develop a weapon based on nuclear fission" (*Copenhagen*, 10, 11). Beyond the customary (and here, blackly) comic effect of dramatic irony, there is an important implication in these naive assumptions, and even more markedly so in Bohr's later assertion that

> mercifully [...] to produce even one gram of U-235 would take 26,000 years. By which time, surely this war will be over. So he's wrong, you see, he's wrong! (*Copenhagen*, 34)

Bohr's certainty that enough U-235 cannot be separated is heightened by the contrast with his darkly comic uncertainty over the duration of the war. In both cases, what comes across most strongly is the fragility of our previous certainties, and scientific certainty in particular. Barnett points out this same disparity and sees that "[t]he obvious contrast between what was considered

scientific fact in 1939 and the reality of Hiroshima and Nagasaki a mere six years later opens up a line of critique that aims at interrogating the nature of scientific fact".[60]

At times, then, Bohr and Heisenberg inhabit the present of 1941, without the benefit of the knowledge of events later in the war and afterwards. At other times Bohr and Heisenberg inhabit the unspecified afterlife, and look back at events after 1941. When they discuss the development of the Allied bomb, they describe, with hindsight, how Frisch and Peierls did the diffusion equation for Uranium 235 and "discovered just how fast the chain reaction would go" (*Copenhagen*, 83), making the idea of a U-235 fission bomb imaginable. But from this position, with the benefit of hindsight, they no longer have access to the knowledge of their own behaviour and motivations that they might have had in the present. Most conspicuously, this is the case with the central uncertainty in the play – why Heisenberg went to Copenhagen. This is clear from the very start of the play: Margrethe reveals that Heisenberg "explained over and over again. Each time he explained it became more obscure" (*Copenhagen*, 3), and Heisenberg agrees that the "more [he] explained the deeper the uncertainty has become" (*Copenhagen*, 4).

This uncertainty that the distance brings is true of other actions, or inactions. When Bohr asks Heisenberg "why didn't you do the [diffusion] calculation?", Heisenberg can only reply:

> **H:** I don't know! I don't know why I didn't do it! Because I never thought of it! Because it didn't occur to me! Because I assumed it wasn't worth doing!
>
> (*Copenhagen*, 85)

Just as with Heisenberg's motivations for going to Copenhagen, he can no longer isolate the reason.

If we wish to, we can make the comparison with Heisenberg's uncertainty principle: the relationship between Heisenberg's knowledge of events and his knowledge of his motivations is a *little* like a pair of canonically conjugate variables (though the analogy is not a strict one). From their vantage of their afterlife, Bohr and Heisenberg can perhaps see relationships between events unclear at the time – they can see that Germany's victory was not certain, that the development of fission bombs was not impossible. But from this position they no longer have contact with the thoughts and motivations that they had at the time: memory is "a curious sort of diary" (*Copenhagen*, 6). The greater their hindsight, the further removed they are from their feelings at that time.

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60 Ibid.

Karen Barad, in a long and detailed criticism of Frayn's play, takes issue with the use of the uncertainty principle in this way – as an analogy for the impossibility of knowing a person's motivations; the analogy I have just described is actually closer to the more rigorous version of the analogy that Karen Barad proposes, which would state something more like 'there is a ratio of uncertainty between our knowledge of a person's actions and of their motivations'.[61] However, Barad has a more general concern – that this sort of analogical use of uncertainty in the play does not say anything more than what would as easily be understood without the analogy. She proposes that a comparison with a quantum mechanical theory is not necessary to argue something as accepted as the fact that "we can [in theory] never know everything about human thinking".[62] Or, in this instance, we could agree that it is hardly a novel contention that, say, 'memory is imperfect', or that 'things look different depending on where and when they are observed from' – and the comparison with quantum mechanics may be seen as window dressing, or worse. As she puts it:

> ultimately it seems that such [analogical] methods (intentionally or otherwise) are only out to garner the authority of science for some theory or proposition that someone wanted to advance anyway and could have advanced without understanding anything at all about quantum mechanics.[63]

This is a fair point, and if the play was only using the scientific content and context to make the above observations, then I think the criticism would be valid. But, in my reading of the play, these contentions are part of a broader analogical aim, one that shows the problems with a scientific monopoly on knowledge. The play does not simply propose that 'memory is a little like quantum uncertainty'. Rather, the uncertainty of our knowledge of events and motivations mirrors the inherent uncertainties involved in quantum mechanics, and in so doing the play begins to extrapolate this to all knowledge, and specifically, the apparent certainty of scientific knowledge.

As they begin the final 'draft', and the temporal perspective once more jumps back to 1941, via the now established trigger of the image of Heisenberg crunching "over the gravel to the Bohrs' front door" (*Copenhagen*, 86), Heisenberg again asks:

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61 Barad, pp. 3-25.

62 Barad, p. 4. The editorial brackets, and their contents, are Barad's. This would appear to be an adaptation of comments made by Frayn in a newspaper interview: "The Uncertainty Principle says that there is no way, however much we improve our instruments, that we can ever know everything about the behavior of a physical object. And I think it's also true about human thinking." Paul Denison, 'Morality Play: Brilliant Minds or Mad Bombers?' *The Register-Guard*, 3 April 2005, section G5.

63 Barad, p. 18.

H: [...] Why have I come? I know perfectly well. Know so well that I've no need to ask myself. Until once again the heavy front door opens.

B: He stands on the doorstep blinking in the sudden flood of light from the house. Until this instant his thoughts have been everywhere and nowhere, like unobserved particles, through all the slits in the diffraction grating simultaneously. Now they have to be observed and specified.

H: And at once the clear purposes inside my head lose all definite shape. The light falls on them and they scatter.

(Ibid.)

Here again it is conspicuous that, as he returns to the present of 1941, Heisenberg is in no doubt as to his motivations – it is only later that they become, to use Margrethe's apposite word, "obscure". There is a subtlety in this exchange that is not immediately evident. For both Bohr and Heisenberg, the "flood of light" that comes from the house – photons fired at the particle that is Heisenberg's motivations, his thoughts – is responsible, ironically, for obscuring the nature of those thoughts. But careful reading of their two responses reveals an important distinction: for Bohr, in the moment before the light hits them, in the moment before observation, Heisenberg's thoughts have been "everywhere and nowhere" – they have no determinate position at all; for Heisenberg, on the other hand, his purposes were "clear", they had a "definite shape", but the impact of the light causes them to scatter. This is a brilliantly economical description of the distinction between their interpretations of quantum mechanics: for Bohr, a particle cannot be said to *have* a position before we make a decision about how we are going to interpret the light that we shine on a particle (as a particle, or as a wave?); Heisenberg's uncertainty principle sees the particle as having a position, but that the act of firing the photon at it alters it in the process of observing it.

All attempts at certainty in the play are confounded. In particular, as I have shown, the uncertainty associated with science actually plays out on two levels: the first, on the subatomic level, in the impossibility of observational certainty that is the result of the uncertainty principle and complementarity, but also on a historical level, in which scientific 'certainties' are seen to be temporary. On all levels – historical, personal, scientific – "the unreliability of the available evidence is built into the play's dramaturgy".[64]

[64] Barnett, p. 142.

4.4 Ian McEwan: Determinism and Contingency

The texts that I have looked at up to this point present critiques of science's epistemic self-confidence by drawing, in ways I have shown, on anti-deterministic implications apparently inherent in theoretical advances in the physical sciences. Both the plays I have examined – *Arcadia* and *Copenhagen* – undermine the possibility of determinism, partly by revealing the difficulties in reconstructing cause-and-effect. As they do so, both texts move a small distance away from realism. To adopt a term coined by Susan Strehle in her study *Fiction in the Quantum Universe*, these plays could be classified, along with Pynchon's novels, as 'actualistic'. Strehle sees the binary division of fiction into realist and anti-realist as unhelpful, especially its consequence of uncritically categorizing all postmodern fiction as anti-realist. Strehle derives the term from "a distinction Werner Heisenberg makes between the actual and the real", and sees actualism as a direct consequence of the attempt to express the uncertainties implied by the new physics:

> Actualistic fiction expresses, then, a literary version of the reality constituted by fundamentally new physical theories in the first half of the twentieth century. Departing from the stable material reality underpinning Newtonian science and realistic fiction, actualism abandons and even subverts the narrative conventions of realism.[65]

Other novels that I have discussed, such as *Time's Arrow*, subvert traditional linear narrative form in order to resist over-determination. In this case, the events described are realistic, but their narrative formulation is quite clearly not.

Turning to the novels of Ian McEwan – I will concentrate on *Enduring Love* and *Saturday*, but also refer to his newest novel, *Solar* – we find neither of these strategies: his later novels are often praised for their realism and, in *Saturday* and *Enduring Love* in particular, the narrative is conspicuously chronological and broadly continuous. Nonetheless, I will argue that there is a resistance to determinism in these novels, but one not immediately obvious because it is masked by protagonists who themselves implicitly and explicitly support deterministic interpretations of events. Moreover, in these two novels the relevance of these arguments concerning determinism is explicitly linked to questions of the relative status of scientific epistemology and alternative systems of knowledge, perhaps even more so than in the texts already discussed.

McEwan's 2005 novel *Saturday* is an account of a single eventful day in the life of a neurosurgeon Henry Perowne, beginning "Some hours before dawn" and ending as he slips into sleep, thinking,

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65 Susan Strehle, *Fiction in the Quantum Universe* (Chapel Hill: University of North Carolina Press, 1992), p. 7.

finally, "this day's over".[66] The two central episodes in the novel involve two encounters with a man named Baxter: the first when they are involved in a minor car accident that leads to a violent confrontation; and later when Baxter forces his way into Perowne's house and threatens his wife and daughter. During the first encounter Perowne diagnoses that Baxter is suffering from some pathology, probably Huntington's disease, and uses the information to "escape a beating" (*S*, 211) but also to, partly unintentionally, humiliate Baxter in front of his two sidekicks; in the second episode, the violence and danger of the situation is defused when Perowne's daughter, Daisy, recites Matthew Arnold's 'Dover Beach'.

There are striking similarities between *Saturday* and McEwan's earlier novel *Enduring Love*. It has been observed that McEwan's novels frequently enact the disruption to a (generally middle-class) life that a traumatic event can bring about, and, often, the ensuing pressure on relationships. James Wood, for example, has described McEwan as "the great contemporary stager of traumatic contingency as it strikes ordinary lives".[67] In *Enduring Love* this is a balloon accident, in *Saturday* a car accident – the dual meaning of 'accident' is significant here. In his novels relationships are often broken or disrupted because two characters react to a chance traumatic event in different ways, as is the case in, say, *The Child in Time* or *Enduring Love* or even *On Chesil Beach*. In *Enduring Love* the traumatic event that opens the novel is a balloon accident in which, due to a "fatal lack of cooperation", and due to a struggle between altruism and selfishness in which the latter wins, one man falls to his death.[68] In the aftermath of the tragedy the novel's protagonist and narrator Joe Rose encounters Jed Parry, who becomes obsessed with him and begins to stalk him, the stress of which results in the disintegration of Joe's relationship with his partner Clarissa.

Enduring Love and *Saturday* are similar to each other in the way that they fit into, but also vary from, the model that Wood observes. In both novels the 'event' (the balloon accident, the car accident) is similar in that it is a traumatic experience but one which *in itself* has only a limited direct effect on the events of the rest of the novel. In both cases, this event also brings the protagonist into contact with another character – an antagonist – who is more disruptive than the original catastrophe (Jed Parry, Baxter). These antagonists are also similar: in both cases their behaviour is affected by a pathological tendency towards extremes of emotion that culminates in violence – strikingly, both novels culminate with the protagonist's wife held at knife point.[69] In

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66 Ian McEwan, *Saturday* (London: Vintage, 2005), p. 3, p. 279. All subsequent references are to this edition, hereafter *S*, and will be made in the text.

67 James Wood, 'James Wood writes about the manipulations of Ian McEwan', *London Review of Books*, 30 April 2009, pp. 14-16 (p. 14).

68 Ian McEwan, *Enduring Love* (London: Vintage, 1998), p. 2. All subsequent references are to this edition, hereafter *EL*, and will be made in the text.

69 Clarissa and Joe are not married, but the appendix describes her as his "common-law wife" (237).

other words, Baxter does not come to exact revenge on Perowne for his humiliation because of the car accident, but because he is Baxter, and is not in control of his mood swings. Similarly, Jed Parry does not start harassing Joe *because* of the balloon accident, but because of an irrational belief that Joe is in love with him.[70] The initial trauma in these novels – unlike in, say, *The Child in Time* – is only the catalyst for the true crisis that will face the novels' protagonists.

Baxter is, as James Wood puts it, "contingency personified, [...entering] Henry Perowne's life in *Saturday* through that most random of urban events, the car accident".[71] In *Saturday* and *Enduring Love* there is an additional link in the chain of cause-and-effect, one that increases the contingency of these novels' narratives: it is not even the chance traumatic event that sets in train the events of these novels, but the meeting with a character *in combination* with that character's pathological predisposition to react to that chance meeting in a certain way. This is significant because the novels are themselves interested in interrogating causality and determinism: if on the one hand these highly contingent events might appear to reduce the narratological determinism, then, on the other, the protagonists at times seem to view the progression of events in an almost simplistically deterministic manner.

The opening of *Enduring Love* is aware of the tension between an apparent determinism, and the contingency of the situation and the possibility of other sequences of events. Narrated retrospectively, the events clearly are pre-determined, and the opening chapter seems at first to confirm this. Joe's narrative frequently glances forward, in more or less explicit ways, to the tragic outcome of the balloon accident and beyond: "Knowing what I know now, it's odd to evoke the figure of Jed Parry" (*EL*, 2); "By the time it happened – the event I am about to describe, the fall" (Ibid.); "our fatal lack of cooperation" (Ibid.); "if I had been uncontested leader the tragedy would not have happened" (*EL*, 11); "at the inquest" (*EL*, 12), and so on. In so doing, this opening asserts the teleology of the narrative; or rather, it undermines the possibility of a conventional pretence that the narrative is not predetermined.

By contrast, there is also a sense that, given the contingency of the balloon as it enters Joe and Clarissa's life, there were other possibilities. Joe sees the balloon as responsible for setting events on their path: "The beginning," the novel opens, "is easy to mark" (*EL*, 1) as the moment when Joe hears a man shout, but just a few pages later Joe pauses his narrative as the men run towards

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70 Although McEwan's 'hoax' appendix describing the apparently real source for Jed's character does note that it is possible that the intense nature of the balloon accident may have brought on the erotomania of de Clérambault's syndrome, the disintegration of Joe's normal life is due to Parry's obsession, not directly the balloon accident.

71 Wood, 'The manipulations of Ian McEwan', p. 14.

the balloon "because it was a time when other outcomes were still possible" (*EL*, 2). Joe obviously makes a decision to run to help, but this fact is concealed in these opening pages in short sentences that resist causal connection: "We turned to look across the field and saw the danger. Next thing, I was running towards it. The transformation was absolute: I don't recall dropping the corkscrew, or getting to my feet, or making a decision" (*EL*, 1). The elision contained in those full-stops is part of a broader pattern: although Joe is of course a rational scientist who sees his own actions as having important and, to an extent, predictable consequences, he also sometimes takes comfort from seeing events as determined, beyond the control of his own decisions.

As Joe's narration pauses after Logan's fall to take stock – "Best to slow down" (*EL*, 17) – he notes that although he has "already marked my beginning, the explosion of consequences" in reality

> this pinprick is as notional as a point in Euclidian geometry, and though it seems right, I could have proposed the moment Clarissa and I planned to picnic [...] or when we decided on our route, or the field in which to have our lunch, and the time we chose to have it. There are always antecedent causes. A beginning is an artifice. (Ibid.).

'Planned', 'decided', 'chose': it is conspicuous that these alternative possible beginnings, these antecedent causes, are decisions that Joe and Clarissa make, as opposed to the contingent external intervention with which Joe chooses to open the story. Joe prefers to see the true cause of the subsequent events as the contingent trauma of the balloon accident as opposed to the decisions that they made.

The tension between the inevitability of events and the possibility of alternatives outcomes is mirrored in the progress of Joe's narrative, which concedes the ineluctable onward rush of events, but retains the possibility of interrupting and delaying them. One such example has already been mentioned, but is worth quoting in full: "I'm holding back, delaying the information. I'm lingering in the prior moment because it was a time when other outcomes were still possible" (*EL*, 2). Indeed, this is precisely what McEwan does, leaving the men "running towards a catastrophe" in order to step back – the beginning is not the beginning after all – and have Joe describe the hours leading up to that "pinprick on the time map" (Ibid.): buying a picnic, his thoughts at the airport, Clarissa's arrival, driving out to the Chilterns, a conversation about Keats, and so on. For McEwan the point is not, as for Joe, to pause while other outcomes are possible, but is part of what James Wood has identified as McEwan's "addict[ion] to the withholding of

narrative information, the hoarding of surprises, the deferral of revelations".[72] In this opening scene the balloon is initially described as "the colossus in the centre of the field" but it is three further paragraphs before McEwan reveals the nature of the danger. And at the point that the narrative pauses, we are aware that something traumatic is about to happen, but the momentum is resisted for five pages. Later, a moment before the gust hits the balloon that will lift the men off the ground, a pivotal moment in the events that lead to Logan's death, Joe again breaks the progression of the narrative: "but before I let it [the gust] reach us, let me freeze the frame – there's a security in stillness – to describe our circle" (*EL*, 12). Joe's desire to control the course of events is palpable, but his ability to do so is limited to literally 'delaying the inevitable': the gust will hit, the events are predetermined, his control is only that of the storyteller.

Many of the contradictions and complexities of the opening of the novel find expression in the first extended scientific metaphor.

> I'm holding back, delaying the information. I'm lingering in the prior moment because it was a time when other outcomes were still possible; the convergence of six figures in a flat green space has a comforting geometry from the buzzard's perspective, the knowable, limited plane of the snooker table. The initial conditions, the force and the direction of the force, define all the consequent pathways, all the angles of collision and return, and the glow of the overhead light bathes the field, the baize and all its moving bodies, in reassuring clarity. I think that while we were converging, before we made contact, we were in a state of mathematical grace. (*EL*, 2-3)

This image of the field as a snooker table references the billiard balls of an archetypal description of Newtonian laws of motion, and its contention that the initial conditions define all the subsequent outcomes confirms the Newtonian ideal of determinism. And yet there is a clear contradiction in these lines: the initial conditions apparently define "all the consequent pathways", but Joe also believes, or wants to believe, that this was a time "when other outcomes were still possible". This passage synecdochically expresses the larger contradiction in Joe's character already hinted at: he at once wants to believe in the possibility of determinism within a system, in so far as it confirms the logical and rational nature of the world – and one accurately described by science; and yet at the same time Joe asserts the possibility of free will and our power to affect events.

McEwan compares the situation, the moments prior to the accident, to an experiment in Newtonian motion, deliberately blurring the boundaries between the two terms of the metaphor: "the overhead light" which should hang over the snooker table "bathes the field" in light, while

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72 Wood, 'The manipulations of Ian McEwan', p. 14.

the buzzard seems to hover over the snooker table; the "moving bodies" can of course refer either to the "six figures" converging on the balloon, or the bodies (as in, for example, planetary bodies) in a Newtonian system. But the predictability of the "consequent pathways" is restricted to the "knowable, limited plane" of the snooker table – such precision is lost in the confusion of real events. In *Arcadia*, Thomasina realised that Euclidian geometry and Newtonian mechanics cannot fully describe the real world: "Mountains are not pyramids and trees are not cones" (*Arcadia*, 84);[73] similarly, in the moment of "grace" before the figures "made contact" (and also, of course, before 'the fall'), when the situation still resembles an isolated laboratory experiment, the consequences may be predictable; once human complexity enters the picture the deterministic system breaks down. This additional complexity is imaged as a fatal third dimension: while events appear to be occurring on a "flat green space", in the two-dimensions of the "limited plane of the snooker table", there is a "comforting geometry" – tragedy comes in the form of the balloon, dramatically introducing the third dimension, and disrupting the predictable, deterministic course of events.

Henry Perowne shares some of Joe Rose's contradictory impulses. I will examine Perowne's adherence to a biological or genetic determinism in chapter 6, but I would like to look here at a moment early in *Saturday* when, as he watches a plane coming down in flames over London, Perowne "remembers the famous thought experiment he learned about long ago on a physics course" (*S*, 18). The thought experiment is Schrödinger's and I will quote the description of Perowne's thoughts in full:

> A cat, Schrödinger's Cat, hidden from view in a covered box, is either still alive, or has just been killed by a randomly activated hammer hitting a vial of poison. Until the observer lifts the cover from the box, both possibilities, alive cat and dead cat, exist side by side, in parallel universes, equally real. At the point at which the lid is lifted from the box and the cat is examined, a quantum wave of probability collapses. None of this ever made any sense to him [Perowne] at all. No human sense. Surely another example of a problem of reference. He's heard that even the physicists are abandoning it. To Henry it seems beyond the requirements of proof: a result, a consequence, exists separately in the world, independent of himself, known to others, awaiting his discovery. What then collapses will be his own ignorance. Whatever the score, it is already chalked up. And whatever the passengers' destination, whether they are frightened and safe, or dead, they will have arrived by now. (*S*, 18-19)

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[73] The full Mandelbrot quotation, the opening of the introduction to *The Fractal Geometry of Nature*, runs: "Why is geometry often described as 'cold' and 'dry'? One reason lies in its inability to describe the shape of a cloud, a mountain, a coastline, or a tree. Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line." Benoit Mandelbrot, *The Fractal Geometry of Nature* (New York: W.H. Freeman, 1982), p. 1. Stoppard probably found the quotation in James Gleick's *Chaos*, p. 98.

Perowne's rejection of the implications of the thought experiment indicate his strong belief in scientific realism – in the existence of fully determinate values 'out there' – but it also suggests his support for the deterministic view that "the initial conditions [...] define all the consequent pathways" (*EL*, 2), to return to Joe's formulation – that, in other words, "Whatever the score, it's already chalked up." This is consistent – as we will see in chapter 6 – with Perowne's repeatedly stated belief in a form of genetic determinism. But the reference to 'the score' might also invite us to compare this view with Perowne's attitude during his squash game with Jay Strauss, in which he clearly does not believe that the result is predetermined – on the contrary, he sees his own actions and decisions as having a significant effect. When Perowne leaves the court to compose himself, for example, he tells himself that "[i]n this moment or two alone, he must think carefully about his game, cut to the fundamentals, decide what he's doing wrong and fix it" (*S*,107).

The reference to Schrödinger's cat is complicated by the fact that it appears that Perowne has misinterpreted the purpose of the thought experiment. The idea, as originally proposed by Schrödinger in 1935, was a criticism of the Copenhagen Interpretation of quantum mechanics; the idea of the cat was a sort of parody or critique – it was intended to illustrate the logical absurdity of the implications of quantum mechanics as it then stood. Schrödinger was unhappy with the idea of quantum superpositions that only undergo collapse into a definite state when they are observed, and the thought experiment constructs a situation in which such a superposition might have a more macroscopic consequence – one that more clearly shows the problem with superpositions. It is important to realise that Schrödinger was not proposing that dead-and-alive cats really exist, but rather that their existence in the thought experiment reveals a problem, or at least an incompleteness, in quantum mechanics.

It therefore makes little sense to observe that the thought experiment does not make "any sense [...] at all. No human sense", since this was precisely Schrödinger's point. Nor is it clear what Perowne might mean when he says that "even the physicists are abandoning it", unless he means abandoning the Copenhagen Interpretation that Schrödinger's thought experiment criticises. Perowne's comment that the idea of simultaneously alive and dead cats is "[s]urely another example of a problem of reference" connects his rejection of the idea back to objections he has already raised to superstition and religion: "The primitive thinking of the supernaturally inclined amounts to what his psychiatric colleagues call a problem, or an idea, of reference" (17). His objection is that religion is essentially anthropic, centring the world on one's own experience, and involves "an inability to contemplate your own unimportance" (Ibid.). The notion that the cat's fate may be dependent on our intervention seems to Perowne to involve the same inflated sense

of our own ability to control events. For Perowne the cat's fate, as with the passengers on the plane, is already determined.

It is perhaps unsurprising that Perowne, "the professional reductionist" (*S*, 272), the "unredeemable materialist" (*S*, 134), should find the counter-intuitive implications of quantum mechanics unfathomable. Near the end of the novel, Perowne sits in the ward with the unconscious Baxter and contemplates his thoughts: they have "assumed a sinuous, snaking quality [...] Feelings have become in this respect like light itself – wavelike, as they used to say in his physics class" (*S*, 262). McEwan initially appears to be using this reference to complementarity – light's simultaneous and contradictory characteristics of both particle and wave – gratuitously, merely in its figurative "sinuous" sense. But Perowne also notes that "he's alive to too many contradictory impulses" (Ibid.) – his thoughts have also taken on the duality of light. As Perowne sits there he wants to "break them [his thoughts] down into their components, the quanta, and find all the distal and proximal causes; only then will he know what to do, what's right" (Ibid.). Perowne's desire is explicitly reductionist, but the reference to quantum mechanics reveals the contradictions, the duality, of Perowne's position: quantum mechanics legislates against the possibility of finding *all* the distal and proximal causes of events – there is a necessary epistemological limit to our knowledge of the causes of things.

This may also illuminate the earlier example. Like Joe Rose, it seems that Perowne believes in causally determined systems, but only in so far as they do not impinge upon his ability to affect the course of his own life. It is perhaps really this that Perowne objects to in Schrödinger's vision – the impossibility of knowing or affecting the outcome. This, and McEwan's engagements with physics more generally, goes to the heart of the common reaction to determinism – we see the logic of causality, and want our decisions to have a causal impact on the future, but cannot quite reconcile our idea of free will with a deterministic view of the universe.

It is notable that what Perowne is trying to understand as he sits with Baxter, through his process of rational reductionism, is "what to do, what's *right*" (my emphasis). This idea, of an ethics based on a scientific method – observation and induction – is also one of the much-misunderstood aspects of *Copenhagen*. Karen Barad, in particular, is critical of Frayn for using the uncertainty principle as an analogy for moral uncertainty. She argues that Frayn forms his own uncertainty principle analogical to Heisenberg's, which suggests that just as we cannot know the position and

momentum of a particle simultaneously, so we cannot understand the actions and motivations of a person. The result, Barad claims, is that "moral judgments [in the play] lose their foundation".[74]

It is necessary to quote Barad at length:

> [The question] that really interests him [Frayn] is the metaethical question of how it is possible to make moral judgements at all. Frayn puts it this way: "The moral issues always finally depend on the epistemological one, on the judgement of other people's motives, because if you can't have any knowledge of other people's motives, it's very difficult to come to any objective moral judgment of their behaviour." But how does this dilemma arise? Why can't we have any knowledge of other people's motives and intentions? According to Frayn, the root of the dilemma derives from the analogy he wants to draw with Heisenberg's uncertainty principle [...] But if the goal is to set up an uncertainty principle for people in analogy with the famous one that Heisenberg proposes for particles, and one is committed to doing so with some care, then it does not follow that "we can't have *any* knowledge of other people's motives".[75]

There are a number of slippages within this passage: careful reading reveals that the questions that Barad apparently draws out of the quotation from Michael Frayn (from a talk for the Niels Bohr Historical Archive's History of Science Seminar, November 19, 1999) do not actually have any basis in it. Let us state clearly what Frayn actually says: that moral judgements require knowledge of motive; that if you can't have any knowledge of motive, it is hard to make moral judgements; and that therefore moral judgements are also epistemological issues. It is unclear where the final quotation in the passage comes from but, with the emphasis placed as it is, it is not, I think, a conclusion with which Frayn would concur. Indeed, in an interview Frayn notes that although it is "extremely difficult [...] to know why people do what they do" he continues: "Not all the time, of course; there are simple cases – when someone's very hungry you could be reasonably confident that's why they've elected to eat something."[76]

Barad attributes to Frayn the idea that we can't have any knowledge of a person's motives; but Frayn says in the same interview that "[a]ll the time we make assessments of people's motives".[77] In an analogy with macroscopic physics he observes that "you can make good practical guesses":

> For all practical purposes, you can tell where you are in the street, even where a fast car is [...] even where a planet is going to be in a year's time [...] It's the same with explanations of why people do what they do: for a lot of practical

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74 Barad, p. 5.
75 Barad, p. 7.
76 Wu, pp. 214-5.
77 Wu, p. 215.

> reasons, you can disregard the problems, you can work on rough approximations, and we do all the time, we have to.[78]

Barad's argument continues by taking her reader through a reimagining of the play which uses Bohr's principle of complementarity as its structuring analogy, in place of Heisenberg's uncertainty. As Frayn accurately points out in the play, Heisenberg conceded to Bohr's interpretation in a postscript to his paper on uncertainty (*Copenhagen*, 69). The distinction between the two interpretations is a subtle but important one, and can be summarised as the difference between an epistemological and an ontological interpretation: Heisenberg's principle is that we cannot *know* both the position and momentum of a particle simultaneously; Bohr's more counter-intuitive principle of complementarity states instead that particles do not *have* determinate values of position and momentum simultaneously. Depending on the measuring apparatus used, different variables become determinate, but certain variables are complementary – the same apparatus cannot give definite values for all variables: "Complementary variables require different – mutually exclusive – apparatuses [...] for their definition, and therefore these variables are reciprocally determinable (when one is well defined, the other can't be)".[79] Barad uses this shift from uncertainty to complementarity to create a complex argument that revolves around the complementary nature of "thinking about something and thinking about thinking about it": "you need to make a choice between two complementary situations: either you think about something, in which case that something is the object of your thoughts, or you examine your process of thinking about something, in which case your thoughts about what you are thinking (about something) and not the something itself, are the objects of your thoughts".[80] The same logic, she argues, could be applied to our thoughts regarding intentions: the result of this argument is that instead of thinking, as she supposes Frayn does, that we cannot know everything (anything?) about intentional states of mind, we should rather acknowledge that the very notion of a determinate intentional state of mind needs rethinking. Rather than thinking of intentionality as something determinate that belongs to an individual, we need, following Bohr, to examine the material conditions (the analogue to the experimental apparatus) that would give intention a determinate existence. These would be "a complex network of human and nonhuman agents, including historically specific sets of material conditions that exceed the traditional notion of the individual".[81]

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78 Ibid.
79 Barad, p. 20.
80 Barad, p. 21.
81 Barad, p. 23.

But the plays' arguments regarding intention and ethics are more complex than Barad supposes. She sees Frayn's implication of moral uncertainty as simply a means to "get history to back off from issuing any harsh judgements against Heisenberg".[82] However, having decided that this is Frayn's agenda, she becomes blind to the uses to which Frayn can put his analogical comparison. Far from, as Barad puts it, "uncertainty sav[ing] Heisenberg's tormented soul from the judgements of history" the fact that Heisenberg remains condemned for his (in)actions (witness the articles regarding the play), whilst Bohr (and indeed many of the physicists more influential in the allied bomb project at Los Alamos) are not, testifies to the fact that an ethics based upon external observables does not work. [83] This, far more than "Heisenberg's lengthy homily on how if we made judgments only on the basis of actions, then the SS man who didn't shoot him when he had his chance near the war's end would go to heaven", is the evidence that the "strange new quantum ethics" (*Copenhagen*, 92) that Heisenberg proposes is ironic.[84] From this position, then, Frayn is able to go in a different direction to Barad, but ultimately end up in a similar place. Barad shows, through a reworking of Frayn's concept, but using a more rigorously defined version of complementarity, that understanding intentionality would require attending to the complex of material conditions that "give it meaning and some sense of existence", and that these would be "political, psychological, social, scientific, technological, and economic" and would also involve the issues of "race, religion, nationality, ethnicity, sexuality, political beliefs and mental and physical health" associated with Nazi thinking.[85] The implication of the audience in the play, as I have shown, seems to me to suggest that the process of knowing intentionality, including one's own intentions, is one that can be mimicked and examined by the literary process. After all, the lists above seem to be a roll call of issues habitually examined by literature. The material conditions that make intentionality determinate are more suited to an examination by literary means than by quantum mechanical ones. This is not to say that Frayn's play, or any other, can 'solve' the problem of Heisenberg's motivation; but then, Barad does not propose a solution either. Instead, she argues, one of the implications of Bohr's philosophy-physics is that "*the very nature of intentionality needs to be rethought*"; rethinking commonly held ideas is precisely what a piece of literature can attempt.

An episode in *Solar* would appear to confirm that McEwan also sees the limitations to the analogy between Heisenberg's uncertainty principle and moral uncertainty. Michael Beard, the Nobel prize winning physicist at the centre of the novel, is listening to a "gangling novelist called Meredith" announce that "Heisenberg's Uncertainty Principle [...] encapsulated for out time, the

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82 Barad, p. 9.
83 Barad, p. 5.
84 Barad, p. 17.
85 Barad, p. 22.

loss of 'moral compass', the difficulty of absolute judgements". Beard responds that actually the principle is "not incompatible with knowing precisely the state of, say, a photon, so long as one could observe it repeatedly", but more importantly that Heisenberg's "principle had no application to the moral sphere" and would only have "application [to the moral sphere] if the sum of right plus wrong divided by the square root of two had any meaning":

> Beard brought his fist down hard on the table. 'So come on. Tell me. Let's hear you apply Heisenberg to ethics. Right plus wrong over the square root of two. What the hell does it mean? Nothing!'[86]

The assertion of the inadequacy of an ethics based exclusively on science is part of what I perceive to be a broader critique of the prioritisation of science as an epistemology. Michael Beard silently ridicules the notion that his girlfriend Melissa is attracted to older men because she nursed her dying father: "this was the kind of nonsense that science was invented to protect him from [...] so many unexamined assumptions, so many unproven elements!" (*Solar*, 166). But McEwan gently undercuts him, finishing the section with a slight redressing of the balance: "He was further irked to hear that when she met her first serious love [...] he was the same age as her father when he died" (*Solar*, 167). Michael Frayn's play also reveals the insufficiency of a simply scientific approach to understanding human actions and motivations. Despite all their revisiting, and redrafting of the events of that day in 1941, the three characters get no nearer to the truth. In fact, the only truth that they end up with is that perhaps sometimes it is best not to know everything. This may not represent the most historically accurate conclusion to the play – as Frayn admits, it is "very unlikely"[87] that Heisenberg's conversation with Bohr had a significant impact on the German bomb project – but this is "the wisdom of the play's inconclusiveness".[88] The final 'draft' confirms that the play is not about the impossibility of making moral judgements of people's behaviour (as Barad seems to think that it is), but rather the insufficiency of certain systems for making moral judgements about behaviour – such as a system that only takes in to account observable quantities. Instead, a moral system needs to account for motivation and intention, a subjective judgement. This, I would argue, renders science epistemologically partial: other epistemological systems – such as the fictitious reconstruction of conversations taking place on stage – are required to make sense of moral issues.

The incompleteness of scientific knowledge is seen, by these texts, as exemplified by the impossibility of the reconstruction of human action or explanation of human motivation. But

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86 Ian McEwan, *Solar* (London: Jonathan Cape, 2010), p. 76, p. 77. All subsequent references are to this edition and will be made in the text.

87 Wu, p. 221.

88 Robert L. King, 'The Play of Uncertain Ideas', *The Massachusetts Review*, 42 (2001), 165-75 (p. 175).

other branches of the natural sciences take exactly this as their aim: as we shall see in chapter 6, Perowne has little problem with explaining human behaviour in terms of the long reach of genetic determinism, although even then he is not without his moments of doubt. Perowne's acceptance of genetic determinism does not amount to a belief that genes are the cause of all our actions and reactions, but nonetheless the idea that our genes have a significant impact not only on our physical appearance or pathologies but also on our behaviour has gained considerable traction. In the next chapter I will show how popular science writing on genetics and evolutionary biology – 'the modern synthesis' – has tended to foster the belief that our genetic make-up and our evolutionary development are critical determining factors: that it is genes or instincts, rather than environment or our free will, that control us.

5 Biological Determinism in Popular Science Writing

Most popular science writing on biology can be divided into one of two broad categories: evolution or genetics. That is to say, the development of species over evolutionary timescales on the one hand (phylogeny); and, on the other, the genetic causes of development of the individual organism (ontogeny). These processes are frequently presented in such a way as to suggest their determined or teleological nature. Whereas in my discussion of popular physics the metaphors that emphasised the indeterminism of physics supported those texts' explicit arguments, suggestions of evolutionary inevitability or genetic determinism sit uneasily within the theoretical positions proposed by these texts. The implication of evolutionary or genetic determinism is not, then, to be found in direct statements, but is rather, to quote Gillian Beer, "concealed in [the] interstices" (*DP*, 56) of these texts.

In the first section of this chapter, I will examine the representation of the role of genes in the development of the individual organism. Although the overarching arguments put forward by these texts are predominantly in line with the view that genes are responsible for an organism's development only in conjunction with developmental processes on a molecular and cellular level, and with environmental conditions on molecular, cellular and organismal levels, I will show that the metaphors used in many popular science texts to describe DNA, genes, and the expression of genes in the phenotype, emphasise the role that genes play, and play down the importance of environmental factors. In short, the metaphors chosen tend to imply the simplicity and directness of the connection between genes and the phenotypic expression in the organism. In this section I will discuss some of the more pervasive metaphors: genes as language (especially writing); genes as a computer program; and genes as a blueprint for a building, or as a recipe for a cake.

In the second section, I will show that a concealed determinism is also to be found in popular accounts of the processes involved in the evolutionary development of species, in the idea of evolution as a teleological process – as progressive rather than simply adaptive. The images used and the narratives constructed suggest that evolution has been inevitably directed towards the current point, with particular emphasis on our own species' evolution as the *telos* – even while these same popular science texts may criticise precisely this (mis)representation. I will concentrate on one particular narrative often present in these popular science books – that of a normatized

account of scientific progress – and show how, as this is in turn conflated with a narrative of evolutionary progress, the idea of scientific *self*-knowledge, the ability to theorise our own evolutionary origins, becomes the implied end-point not only of evolutionary theory, but also of the process of evolution itself.

5.1 Genetic Determinism

Genetic determinism is an emotive issue. Unlike physical determinism whose debates rarely range beyond philosophical and scientific boundaries, the implications of genetic determinism impinge directly on human behaviour, and on issues such as society, racial and gender equality, parenting, politics and education. However, the debates are also complex and confusing; not least, again, because of the word 'determinism'. As Steven Pinker points out,

> Attempts to explain behaviour in mechanistic terms are commonly denounced as "reductionist" or "determinist". The denouncers rarely know exactly what they mean by those words, but everyone knows they refer to something bad.[1]

Genetic determinism *should* be relatively easy to define as the determination of all physical and behavioural characteristics of an organism by its genetic material, or genes; but, as we shall see, this is not a useful definition for the forms of determinism that actually exist both within the scientific community, and in popular scientific representations of genetics. Versions of this definition *can* be found – for example in the first chapter of the collaborative book *Not In Our Genes*:

> biological determinists [argue] that human lives and actions are inevitable consequences of the biochemical properties of the cells that make up the individual; and these characteristics are in turn uniquely determined by the constituents of the genes possessed by each individual.[2]

But although Pinker stresses in *The Blank Slate* that "reductionism is not a straw man" – that some scientists do believe that complex social concerns, such as conflict resolution, can be explained by "the biophysics of neural membranes" – genetic determinism, in the extreme form quoted above, certainly is.[3] The authors of *Not In Our Genes* openly admit that their agenda is a "critique of biological determinism and its claim to define 'the nature of human nature'".[4]

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1 Steven Pinker, *The Blank Slate* (Harmondsworth: Penguin, 2002), p. 10.
2 Steven Rose, R.C. Lewontin, Leon J. Kamin, *Not In Our Genes*: *Biology, Ideology and Human Nature* (Harmondsworth: Penguin, 1990).
3 Pinker, p. 70.
4 From the back cover blurb of Rose et al., *Not In Our Genes*.

"Everybody," Matt Ridley asserts in *Nature via Nurture*, "with an ounce of common sense knows that human beings are a product of a transaction between [nature and nurture]".[5] Susan Oyama notes, in her seminal work on developmental systems theory *The Ontogeny of Information*, that the "ease with which extreme nature and nurture positions are parodied ensures that no one will stand behind either straw man".[6] The debate between genetic-determinists and anti-genetic-determinists (or nurturists) seems to be, then, a question of degree, and for this reason I will use the terms 'gene-centric' to refer to those writers who argue for an emphasis on the relative importance of genes in ontogeny, and 'environment-centric' for those who assert the relative importance of environment in the development of an organism. Although environment-centric nurturists – such as Lewontin et al. above – may choose to characterise the gene-centric geneticists as 'hard' determinists, the caricature is even more exaggerated than comparing modern physicists to a Laplacian ideal of physical determinism.

Despite this fact, the link between genetics and determinism in the public consciousness is nonetheless strong, even if determinism in this instance is a weaker form than that under scrutiny in debates within physics. As we shall see, the physicist Erwin Schrödinger played an important role in the conceptualisation of genetics, and he was quick to see the connection between genetics and precisely the form of determinism discussed in chapter 3:

> In calling the structure of the chromosome fibres a code-script, we mean that the all-penetrating mind, once conceived by Laplace, to which every causal connection lay immediately open, could tell from their structure whether the egg would develop, under suitable conditions, into [...] a mouse or a woman.[7]

In this quotation can be perceived the modern debate concerning genetic determinism, encapsulated. In invoking the figurehead of determinism, Laplace, Schrödinger ascribes to genetics a 'hard' determinism; and yet, in that critical internal clause "under suitable conditions", is contained the nurturist's objection to genetic determinism: traits cannot be called genetically *determined* if they rely on environmental conditions. As far as Schrödinger's genetic determinism goes, it is true determinism; but how far it goes, is hardly anywhere.

If no one is an extreme genetic determinist, or a genetic 'denialist', then the broad answer put forward by almost all popular science writing on the subject is an interactionist approach. But

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5 Matt Ridley, *Nature via Nurture: Genes, Experience and What Makes Us Human* (London: Harper Collins, 2003), p. 3.

6 Susan Oyama, *The Ontogeny of Information: Developmental Systems and Evolution*, 2nd edn (Durham, NC: Duke University Press, 2000), p. 2.

7 Erwin Schrödinger, *What Is Life?* (Cambridge: Cambridge University Press, 1944), p. 22.

what the quotation from Schrödinger shows is that *within* the interactionist argument the *representation* of the argument presented can still be determinist or anti-determinist, geneticist or empiricist, or (most likely) somewhere on the spectrum between the two. Those writers towards the geneticist end of the spectrum present an interactionism in which genes determine, within the constraints and alterations brought about by environment; at the other end, empiricists admit that environments cannot, on their own, 'create' an organism, but assert that it is the environmental conditions that control the expression of genes, and thus play a dominant role in development. The former stance is gene-centric; the latter environment-centric.

Both gene- and environment-centric positions allow that ontogeny inevitably involves the interaction of both genes and environment, and indeed 'interactionism' may seem to present a compromise between the opposing groups. But, although "a generally interactionist *vocabulary* is rapidly becoming universal", it is, according to Susan Oyama, a falling between two stools:

> [Another] problem that concerns me is interactionism itself. How does it manage to be virtually universally adopted and thus to lend itself to such radically different approaches? The suspicion is that it has become conceptually vacuous while acquiring the symbolic value of a membership badge, to be flashed upon entry into serious discussion: yes, I belong to the company of reasonable people; now let's talk about the real stuff.[8]

The spreading of this vocabulary, has, in other words, glossed over significant disagreements. Oyama's argument in *The Ontogeny of Information* is that we need to deconstruct the dichotomy of nature and nurture – that *all* of the variants of interactionism, as they are customarily used, merely "combine […] encoded nature with varying doses of contingent nurture", a solution which "is no solution at all".[9] Development, she argues,

> can no longer be explained as a combination of translated information from the genes (to make innate features) and information acquired from the environment (to modify, supplement, or complete those features). Nor can phenotypic features be divided into those that are programmed or biological and those that are not, or ranged on a continuum of relative degrees of programming[.][10]

What this quotation hints at, and what Oyama reveals at the centre of her thesis, is that there are shared assumptions between even the opposing advocates of very different forms of interactionism. The crucial common assumption that she identifies is "a 'preformationist' attitude toward information" itself, information which "is seen to reside in molecules, cells, tissues, 'the

8 Oyama, p. 2.
9 Oyama, p. 5.
10 Oyama, p. 3.

environment', often latent but causally potent".[11] The significance of this list is that it reveals that all the actors in this debate – those that take a gene-centric, or environment-centric stance – locate information as the key to understanding development, and as existing "before its utilization or expression".[12]

Oyama's answer to this underlying problem with our way of thinking about development is to apply the traditional criticism of preformationism of the organism to this preformationism of information. Equating the preformationism of form with that of information she identifies the problem as the notion "that form, or its modern equivalent, information, exists before the interactions in which it appears and must be transmitted to the organism either through the genes or by the environment"; the solution is to see that "[d]evelopmental information itself, in other words, has a developmental history".[13]

In his foreword to the second edition of *The Ontogeny of Information*, Richard Lewontin concludes that

> It is impossible to carry out scientific explanation without metaphors. Indeed we can hardly speak without them. The most we can demand is that we be conscious of the metaphorical content of our words and not be carried away…No metaphors are truly benign and without dangers. As Norbert Weiner observed, "The price of metaphor is eternal vigilance."[14]

He is correct to highlight the importance, and dangers, of metaphors; a key element in Oyama's ensuing critique is her categorisation and analysis of variants on what she calls the "cognitive-causal" gene, or what Stephen M. Downes, in his review of the second edition, calls simply the "information gene".[15] In a chapter entitled 'Variations on a Theme: Cognitive Metaphors and the Homunculoid Gene' Oyama briefly examines metaphors of blueprints, plans, rules, instructions, programs, and, in detail, information in different guises. These metaphors constitute "a cluster of pervasive metaphors rather than being a legitimate component of an explanatory theory"; Oyama believes that "the information gene concept is a metaphor that has seriously misled us".[16] In this chapter I too will concentrate on some of the key metaphors in the debate; however, I will concentrate on their deployment in popular science writing and identify the mechanisms through

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11 Oyama, pp. 1-2.
12 Oyama, p. 2.
13 Oyama, p. 23, p. 3.
14 R.C. Lewontin, Foreword, in Oyama, p. xv.
15 Stephen M. Downes, review of Susan Oyama, *The Ontogeny of Information* in *Perspectives in Biology and Medicine*, 44 (2001), 464-69 (p. 465).
16 Ibid.

which these now standard metaphors support, primarily, a gene-centric, and thus more genetically deterministic, representation of biology in popular science.

5.1.1 The Language of Genes

It has become a cliché to refer to DNA as the 'language of life'.[17] But this metaphor, one of the most common, and indeed formative, in genetics, has its roots in another slightly different metaphor, one coined before even Crick and Watson had formulated their model of the structure of DNA. In 1944 the physicist Erwin Schrödinger first described the chromosomes as containing "some kind of code-script", in his popular book *What Is Life?*: "Every complete set of chromosomes contains the full code" and this embodies "the entire pattern of the individual's future development and of its functioning in mature state".[18] As Susanne Knusden has pointed out, the significance of the metaphor is that it is not simply descriptive of the chemical *properties* of DNA (Schrödinger actually thought the genetic code was held in 'chromatine'), but also of *process*: "the figurative representation [of a code-script] suggests what the chromosomes *do*: they encode 'the individual's future development'".[19] It is partly this fact that results not only in the metaphor's longevity, but also its central place in the subsequent theory-formation of genetics, and its adaptation and revision in subsequent decades. As Lenny Moss concludes, "Schrödinger's artful rhetoric did much to shape the terminological linguistic, and thereby conceptual, space in which the Watson and Crick breakthrough was received a decade later".[20]

It is partly through a secondary metaphor of 'translation' that Schrödinger's code metaphor finds itself increasingly elided with a metaphor of language in popular discourse. Knusden identifies George Gamow as responsible for introducing the 'translation' metaphor in 1955; but concerned as she is primarily with a diachronic study of the 'code' metaphor, she does not mention that the combination of the, at least partly, historically contingent fact of the identification of base pairs by the four letters A, G, T, C, and the, albeit incorrect, translation metaphor inevitably results in the evocation of language. Language is present, where the code metaphor is not, in the passage she quotes from Gamow:

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17 An utterly unscientific Google search at the time of writing for 'language of life DNA' returns 2,100,000 web pages. Similar results are to be had with 'alphabet DNA', 'genes language' and so on. This contrasts with fewer than a million pages returned for 'DNA deoxyribonucleic acid'.

18 Schrödinger, p. 22.

19 Susanne Knusden, 'Scientific metaphors going public', *Journal of Pragmatics*, 35 (2003), 1247-63, (p. 1251).

20 Lenny Moss, 'The Meanings of the Gene and the Future of the Phenotype', *Genomics, Society and Policy*, 4 (2008), 38-57 (p. 38).

> the problem reduces to finding a procedure by which a long number written in a four-digital system (four bases forming the molecules of nucleic acid) can be *translated* in a unique way into a long word formed by about twenty letters (twenty amino acids which form protein molecules).[21]

It is interesting to notice the way in which the metaphor of a digital, number system shifts via the word "translation" to a metaphor of language: a protein "word" formed of amino acid "letters". This is despite the fact that it was the base pairs that had been assigned letters as identification, not the amino acids.

Evelyn Fox Keller has argued that discourses play a crucial role in delimiting the course of future research within a scientific field. Thus, she has asked,

> What then do I mean when I say that the discourse of gene action – now augmented with metaphors of information and instruction – exerted a critical force on the course of biological research? Can words have force in and of themselves? Of course not. They acquire force through their influence on human actors. Through their influence on scientists, administrators, and funding agencies, they provide powerful rationales and incentives for mobilizing resources, for identifying particular research agendas, for focusing our scientific energies and attention in particular ways.[22]

Certainly, in the case of the language metaphor, the power of the discourse in its potential to focus research energies in particular ways was greater even that its explanatory power on the theoretical level. Lenny Moss has noted that "[w]hile the heuristics of 'nucleic-acid sequence as language' did not prove to be biologically fruitful, it left an enduring legacy at the level of the speech-style used to describe and conceptualize molecular-level biology".[23] But more significantly, these failed attempts to reconcile the discourse of language with the theoretical problems in the field did not damage the perceived usefulness or accuracy of the discourse; on the contrary they curiously reinforced it. For example, Moss contends that the language metaphor was influential in suggesting methods of solving the problem of the 'comma-free code'. The comma-free code problem may be explained most easily with an example. Imagine the following string of twelve bases (four codons) which specifies a protein made up of four amino acids, AATCGACATGAA; the codons are, therefore, AAT, CGA, CAT and GAA. However, if we start reading one base later the codons are instead ATC, GAC, ATG and AA?. This is the problem of frame-shifting: the lack of 'commas', or other markers of the boundaries of codons,

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21 George Gamow, 'On information transfer from nucleic acids to proteins', *Det Kongelige Danske Videnskabernes Selskab: Biologiske Meddelelser*, 22 (1955) 1-7. Quoted in Knusden, p. 1252.

22 Evelyn Fox Keller, *Refiguring Life: Metaphors in Twentieth-Century Biology* (New York: Columbia University Press, 1995), p. 21.

23 Lenny Moss, *What Genes Can't Do* (Cambridge, MA: MIT Press, 2003), p. 66.

means that we can't know where each codon starts and ends. The solution proposed by Crick and others "consist[ed] of partitioning all the possible codons (sequences of three [bases]) into those which have 'meaning' and those that don't [...] All the meaningful codons would then constitute a 'dictionary' by their terms. In this way a sequence would be *read* univocally and without the need for punctuation".[24] However, as it turned out this did *not* prove to be the solution to the comma-free code problem; in fact certain codons *do* act as start and stop markers. Despite this, the prevalence of the language metaphor was not affected: "Although this did not prove to be the solution to the comma-free code problem, the rhetoric of textuality grew further and prospered".[25]

Similarly, although Gamow's 'translation' metaphor was indeed replaced by the more accurate 'transcription' metaphor as the two-stage process of conversion of DNA to proteins was more precisely understood, the language metaphor would become a crucial part of the pedagogy of genetics. Although the metaphors of code, and later information, would in the end play more significant roles in theory-formation in genetics – indeed these metaphors have come to be considered by most scientists to be a non-metaphorical part of the scientific discourse of genetics – language remains the dominant pedagogic metaphor in popular accounts of genetics. I will show that, as it is ordinarily used, it simplifies the relationship between the level of the gene and the level of the phenotype (the traits manifested in the organism) by presenting language as an unproblematic, unambiguous system of communication. The following is a fairly representative example of the use of the language metaphor:

> Up to fifteen cistrons are strung together to give a transcription unit (scripton). The scripton corresponds to a compound sentence. Many hundred scriptons make up a replication unit (replicon), which can be compared with a paragraph of text [...] Finally, the gene [...] corresponds to the complete text. The hierarchical organization of a living system on the phenotypic level is directly reflected in the hierarchically organized structure of genetic information.
>
> The analogy between human language and the molecular-genetic language is quite strict [....]
>
> There are admittedly limits to this analogy. For instance, the molecular-genetic language [...] does not contain question marks.[26]

The hierarchical organization of both the living system and of genetic information is noted; but their reflection in the hierarchical organization of language is left implicit. This nesting of units of language is significant because the logical progression – normally, as here, from smallest to largest

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24 Moss, *What Genes Can't Do*, p. 67.
25 Ibid.
26 Bernd-Olaf Küppers, *Information and the Origin of Life* (Cambridge, MA: MIT Press, 1990), p. 23.

– from letter to full text implies an analogous logic to the progression from base pair to organism. This linear progression is even more explicit in the following example:

> The chain links [in DNA] can be likened to letters in a sentence, and DNA to a text or code that tells our bodies what to do. The alphabet consists of four letters [...] Starting with this known alphabet, the task of the Human Genome Project is to learn the sequence of the letters and to read the text. The size of the text is enormous. The card catalogue for the DNA library requires enormous computing capacity.[27]

Here the DNA is a "text [...] that tells our bodies what to do" – there is no implication of other environmental factors. Indeed, the idea that the text tells our bodies what to *do* (emphasis added) carries with it the suggestion of not only physiognomic traits, but behavioural ones.

This reductive progression from gene to organism is a key element in the gene-centric argument; emphasising the role played by genes necessitates disambiguating the link between the gene and the organism. Those metaphors that prioritise the gene as the root cause of physical or behavioural traits tend therefore to work in similar ways rhetorically: by comparing genetics to systems in which the causal lineage is simpler, without the complexities of chemical, environmental, educational and social interventions, they analogously suggest the direct lineage between genes and the trait, playing down the role of environment. On the other hand, in the opposing environment-centric rhetoric, the unitary parts of the system used in the vehicle of the metaphor are imagined as sufficiently affected by environment to represent a holistic sum that is far enough removed as to deny causal priority to the gene.

In general, the use of the language metaphor in popular science writing on genetics falls into the first of these two categories: it tends to reinforce gene-centrism. Language is represented as a system in which the progression from letters and words to meaning is simple, and unaffected by elements outside the system; the analogy suggests that the same is true of the relationship between genotype and phenotype. In order to show this, it is useful to identify three key features of the use of the language metaphor in representations of genetics.

The first common form that the language metaphor assumes is what we may call the 'physical manifestation of language'. In other words, language is normally represented in physical-tangible form – as a book, as a page, as a library. Language, as a metaphor for genetics in popular science writing, rarely means language as an abstract system, or even as speech or dialogue; rather, it

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27 Ted Peters, *Playing God?: Genetic Determinism and Human Freedom*, 2nd Edition (New York: Routledge, 2002), p. 3.

almost always means written words on a page. As a metaphor for the gene this emphasises the gene's physicality, its locatability, its isolation and its unitariness: the gene becomes reified. As José Van Dijck has put it, the terms *gene* and *genome* "become crystallized into things, rather than being fleshed out as complex processes. Reified into entities, they start to function in society as signs with fixed meanings, only to become signifiers in other contexts".[28]

A pervasive double rhetoric, to be found primarily in media representations of genetics, of traits being 'in the genes' and of 'genes for *x* trait' underpins this reification, and thus in turn the simplification that is central to the gene-centric position. (Almost exclusively, this *x* trait is a physical or behavioural abnormality; Van Dijck and others have asked why we "read cover stories about researchers who have found the infidelity gene and the gene for homosexuality, but never hear of researchers looking for the gene for loyalty or for heterosexuality".[29]) As Ruth Hubbard has argued, the public announcement of a successful location of a gene 'for' a disease carries with it the notion of a gene as a physical entity, definitely locatable on the chromosome, isolated from interaction with other genes, and from environmental stimuli.[30] This, what we might call the 'single-gene cause' conception of genetics, is appealing in its simplicity; but Van Dijck has also noted both the fact that it "provide[s] a means of explaining and predicting someone's deviance" and that, furthermore, like other representations of the genome, the "localization of single genes is pivotal to the promotion of genetic therapy as the great eraser of all disease for future generations".[31] Within the Human Genome Project (HGP) context, and given the public perception of the HGP as primarily medical-science research, the social benefit of the HGP and a form of gene-centrism are, then, mutually supporting claims: in order to 'treat' or 'fix' genes 'for' diseases, they must be identifiable and locatable; the resulting implication is that genes as locatable entities are 'for' a trait – a distinctly gene-centric perspective.

Having noted that the manifestation of the language metaphor is almost exclusively textual, the second salient feature of the language metaphor is the kind of texts that are invoked as part of the metaphor. Dictionaries, encyclopaedias, instructions, blueprints, recipes are the paradigmatic texts; there is no instance, to my knowledge, of DNA being described as, say, 'the epic poem of life'. Consider the following examples:

> The [DNA] dictionary maps 64 code words onto 21 meanings [...] Human

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28 José Van Dijck, *Imagenation: Popular Images of Genetics* (Basingstoke: Macmillan, 1998), p. 162.

29 Van Dijck, p. 165.

30 Ruth Hubbard and Elijah Wald, *Exploding the Gene Myth: How Genetic Information is Produced and Manipulated by Scientists, Physicians, Employers, Insurance Companies, Educators, and Law Enforcers* (Boston: Beacon Press, 1993).

31 Van Dijck, p. 165.

> languages are numerous and changing [...] the 64-word DNA dictionary is universal and unchanging.[32]
>
> DNA can be regarded as a set of instructions for how to make a body, written in the *A, T, C, G* alphabet of the nucleotides.[33]
>
> The genome – the sum total of an organism's DNA – was understood to be its book of life, life's little instruction book.[34]

These sorts of texts are chosen because the language is assumed to be unambiguous. The implication is that an unproblematic relationship between language and meaning is analogous to an unproblematic relationship between genotype and phenotype. The uncritical association of language with 'meaning' or 'coding for' is clear in the choice of texts that are used in these textual metaphors. The emphasis on communicative information, and the fixity of meaning in these texts, implies the unambiguous 'translation' of DNA into proteins, and thus into physical traits.

But language *is* ambiguous, and this leads us onto the third feature of the language metaphor. The language metaphors in these books ignore the polysemy of language by taking a syntactic approach to language, rather than a literary one, and by using texts where the stated purpose is instructive or informative. But the result is that these metaphors of language in popular science books on genetics suggest the direct relationship between genotype and phenotype – in other words, gene-centrism. Discussing the similar metaphors of blueprints and programs, Thomas Fogle has observed that

> the comparison of DNA with blueprints and programs engenders the interpretation of genetics as a matching process between a single gene and a trait. This imposes a sense of biological determinism onto what is basically a contingent relationship between biochemical pathways, cellular structures and physiological processes.[35]

The same, I argue, is true also of the language metaphor.

The exceptions in this case prove the rule. Just as the passages I have highlighted establish the centrality of the role of genes over environment through a language metaphor that limits or ignores the polysemy of language, other writers have used the language metaphor to present a more balanced interactionist position, one that acknowledges the importance of environmental

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32 Dawkins, *Ancestor's Tale*, p. 22.

33 Richard Dawkins, *The Selfish Gene*, 2nd edn (Oxford: Oxford University Press, 1989), pp. 22-23. Unless otherwise specified, subsequent references are to this edition, hereafter *SG*, and will be made in the text.

34 Nina V. Fedoroff, Nancy Marie Brown, *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods* (Washington, DC: Joseph Henry Press, 2004), p. 81.

35 Quoted in Van Dijck, pp. 149-150.

factors. Richard Pollack accomplishes this by shifting the ground of this metaphor from a linguistic, syntactic appreciation of the DNA 'text', to a more literary one; thus, just as literary critics propose multiple readings of texts, so "the cells of our bodies do extract a multiplicity of meaning from the DNA text inside them".[36] Pollack's purpose in importing the concepts of literary criticism is to show that "the leap from DNA to protein is as arbitrary as the relation between signifier and signified".[37] Pollack is using the same metaphor as other popular science writers, but for exactly the inverse purpose.

Lenny Moss has provided a similarly nuanced use of the language metaphor. He is even more explicit in citing linguistic and biological context as comparable. Just as – in, say, dialogue – "context [...] determines the significance of the word, not vice versa", so the same might be argued of genes within context:

> Contexts, in a biological vein, would be found at the many levels of structured, dynamic systems that are always in some relationship to other structured, dynamic systems, and/or a complex environmental ambience.[38]

For Moss, it is not the language metaphor itself that is at fault for gene-centric representations of genetics, but the fact that it is misused. On the contrary, he sees the fact that "even the simplest free living cell is capable of considerable adaptive plasticity – i.e. successful participation in highly variant 'dialogical contexts'" as arguing for the great "explanatory potential of depicting genes as words whose significance is context-dependent".[39] The introduction of context into the metaphor "serves precisely to undermine vectoral unidirectionism (all causality emanating outward from the genes as the 'deep text which underlies all else')".[40] What both Pollack and Moss show is that although the language metaphor can be deployed in support of a gene-centric position, it can also be used – indeed, is perhaps better suited – to support an interactionist position that places a greater emphasis on environmental influence.

5.1.2 Language 'Upgraded': The Computer Program Metaphor

In the 1980s and 1990s, with the increasingly widespread use of computer technology, a new set of metaphors for genetics became available, and prevalent. Out of the metaphors of language

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36 Richard Pollack, *Signs of Life: The Language and Meanings of DNA* (New York: Houghton Mifflin, 1994), p. 5.
37 Van Dijck, p. 155.
38 Lenny Moss, *What Genes Can't Do* (Cambridge, MA: MIT Press, 2003), p. 72.
39 Ibid.
40 Ibid.

and code, related metaphors of computer language, computer programs and data emerged. Van Dijck has charted the rise in use of these images in the media, particularly in relation to the Human Genome Project (HGP), and he draws a number of conclusions from his analysis, only some of which are relevant to the present argument. He does, however, recognise the roots of this new set of metaphors in, firstly, the preceding metaphors of 'code', 'information' and 'language' and also in the fact that "the development of genomics was thoroughly dependent on the emergence of computers". Susan Oyama, in her thorough categorisation of "variants of the homunculoid, cognitive-causal gene", distinguishes between metaphors of information, rules, programs and instructions; the distinction between such metaphors in popular science writing itself is, by contrast, often vague. Keller has described the "introduction of the metaphor of information [by Crick and Watson] to the repertoire of biological discourse… [as] a stroke of genius", and the importance of the metaphor of information and information theory for genetics has been examined thoroughly both by Keller and Oyama.[41] I wish to concentrate rather on the metaphor of the computer program, which undoubtedly has its roots in both Schrödinger's "code" and in Crick and Watson's "information", but which is ubiquitous in popular science writing on genetics.

For the purposes of this analysis, the new metaphors of computer data and programs can initially be seen to function in a remarkably similar way to that of language; I will argue that frequently the same implications identified in the use of language metaphors (the simplification of the causal connection between words and meaning, and thus genotype and phenotype) are also often inherent in computer metaphors. Towards the end of this section, I will also examine the ways in which the new set of computer metaphors differ from those of language, and the effects that these differences have on the representation of genetics, and genetic determinism.

That the new metaphors do not really bring about a change in the representation or perception of genetics is a fact repeatedly acknowledged by Van Dijck:

> [This] new set of related images, which, on the face of it, seemed reinvigorated or updated by computer language [...] turned out to be far from innovative.[42]

The new images should have allowed for a more complex understanding of the relationship between DNA and proteins, and indeed it seems likely that it was at least partly the increased complexity within the field of molecular biology in the 1980s – a move away from the uni-directional understanding of this process, to one based on networks and information theory –

41 Keller, p. 18.
42 Van Dijck, p. 121.

that was responsible for these new computer metaphors. However, in the popular literature, this increased complexity did not materialise, rather "the images that evolve along with information processing systems reflect anything but complexity".[43] So, the new breed of metaphors continue to recall the old. The computer metaphors may be sensibly divided into those which figure genes and genetics in terms of computer hardware, and those whose metaphoric vehicle is software. I shall investigate the former, smaller, and more straightforward subset first, before moving on to look at software in more detail.

When computer metaphors gravitate towards hardware – the physical, concrete, rather than abstract, manifestations of the computer system – they strongly recall a similar predilection mentioned in the preceding section on language. To be more specific: just as the genes-as-language analogy is frequently imaged in metaphors of books and libraries, so genes-as-data have been represented as floppy discs, hard drives, CDs, or the computers themselves. Thus Dawkins notes, in an elaborate metaphor (one that, intriguingly he claims is "not a metaphor, it is the plain truth") in *The Blind Watchmaker*, that

> [i]t is raining DNA outside. [...] It couldn't be any plainer if it were raining floppy disks[44]

and in *The Ancestor's Tale* that

> the image of the genome as an old hard disk, badly in need of a spring clean, is one that will serve us from time to time[45]

and Ted Peters imagines that

> The card catalogue for the DNA library requires enormous computing capacity.[46]

The last example shows, in the mixed metaphor that combines the old and the new forms, that these different metaphors are essentially interchangeable. Van Dijck has noted how the idea of a "compact disk containing an inscription of a person's genetic make-up" collapses the "digital, organic and metaphysical signifieds of the body".[47] Just as with language these examples involve a

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43 Van Dijck, p. 123.

44 Richard Dawkins, *The Blind Watchmaker* (Harmondsworth: Penguin, 2000), p. 135. All subsequent references are to this edition, hereafter *BW*, and will be made in the text.

45 Dawkins, *Ancestor's Tale*, p. 22.

46 Peters, p. 3.

47 Van Dijck, p. 123.

reification of DNA, or the genome, that suggests its physicality and locatability, with the consequences examined in the preceding section.

There is something curious, almost perverse, about adopting the computer analogy for genetics, but manifesting it through images of discs and other hardware. Clearly the hardware is ordinarily the point of our own interface with a computer system; nonetheless, the software is the essence of a computer – the hardware is simply a point of access, or a device for storage, control, input or output. Without the software, the computer is a set of inert objects. It is therefore unsurprising that the second category of computer metaphors, those that compare genes and the genome to computer software, or programs, is by far the larger category. Indeed, as Oyama has pointed out: "The genome as constituting rules, instructions or program, either in the sense of a plan or in the sense of a computer program, is so common a notion as not to seem metaphorical at all".[48] But these metaphors replicate one of the central problems of the language metaphors: the increasingly potent metaphor of the genome as a computer program simplifies the complex relationship between the genotype and phenotype in exactly the same way as did the metaphor of words and meanings.

The roundworm *Caenorhabditis elegans*, surely one of the most intensively studied organisms on earth, and the first to have its entire genome 'mapped', Pinker describes as

> a microscopic worm composed of 959 cells grown by a rigid genetic program, with a nervous system consisting of exactly 302 neurons in a fixed wiring diagram. As far as behaviour is concerned, it eats, mates, approaches and avoids certain smells, and that's about it.[49]

Pinker is using this example to highlight the fact that "freedom and diversity of behaviour come from having a complex biological makeup, not a simple one", comparing this worm's genome with the human one. But what this example clearly shows is the connection between the metaphor of the computer program, here extended and almost demetaphorized in the standard image of neurons as wiring, and a gene-centric conception of development. The genetic program is shown to create precise, identifiable and predictable phenotypic characteristics, emphasised in the precision of the numbers and through the terms "grown", "rigid", "exactly", "fixed" and "diagram", and in the limited list of behaviours that lack all semblance of agency. Indeed, as we shall see later, as part of the rhetoric of genetic determinism genes themselves are frequently

48 Oyama, p. 50.
49 Pinker, p. 76.

described with more agency and animation than is this apparently genetically determined organism.

Moreover, there is a revealing slippage between physical and behavioural characteristics. The passage does not explicitly claim that the behaviour of the organism is governed by its genetic program, but the structure of the passage – from the "genetic program" to the nervous system to the list of behaviours – and the paratactical relation between the physical and behavioural elements, certainly implies that these too are governed by the program. The distinction between the genetic determination of physical and behavioural phenotypic elements, while not in itself a necessary distinction, has nonetheless acquired a symbolic importance in the genetic determinism debate.

On the very same page, Pinker also wonders "how many genes it would take to build a system of hard-wired modules, or a general-purpose learning program" – in other words a program metaphor on the level of the brain modules, and one that relies heavily on the computational terminology of cognitive psychology and neuroscience – and also describes "Gene-estimating programs [that] look for sequences in the DNA that are similar to known genes", in other words a genuine computer program that is integral to the practice of genetic sequencing. This illustrates Van Dijck's observation that there is a blurring of the boundary between the representations of the HGP and of the process of the scientific practice itself: the result of the HGP is both a collection of digital units and a methodology of "sequencing genes [...that] now fully consists of processing digital information".[50] In this very specific example, then, "[d]igital inscription devices and storage systems are not merely technological 'upgrades' of old information and language metaphors" but are almost "an unambiguous representation of physical reality".[51]

This confusion of the metaphorical and the literal is symptomatic of the computer metaphor's ubiquity. Such has been its success that the *OED*'s definition for program, in the sense of a set of instructions for a computer, explicitly includes the transferable sense from genetics:

> **program, 9 b.** [...] A series of coded instructions and definitions which when fed into a computer automatically directs its operation in performing a particular task. Also in extended use: something conceived of as encoding and determining a process, esp. genetically.[52]

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50 Van Dijck, p. 123.

51 Van Dijck, pp. 123-4.

52 programme | program, *n.* 9 b., *Oxford English Dictionary*, 2nd edn, 1989, *OED Online*, Oxford University Press <http://dictionary.oed.com/cgi/entry/50189636> [accessed 01 July 2010].

It is interesting to note here not just the direct comparison between the computer program and the genetic one, but also the pairing of the terms "encoding" and "determining", a combination that implies their similitude: computer programs are encoded, and determine; similarly, if genes encode, then they must also determine.

In the preceding section on language I argued that metaphors that compare genes to language routinely limit the potential for the polysemy of language – the same is fundamentally true of the language of computer programs. Ambiguity within a computer program is potentially disastrous and the comparison of genes with the language of a computer program implies (even more strongly than a comparison with language) the fixity of the effect of a gene, and thus its deterministic, rather than environmentally contingent, nature. And as the metaphors of books and libraries have been 'upgraded' to those of computers and hard drives, so the idea of reading now "seems naturally to imply automatic decoding" performed by a machine rather than human reader.[53] Again, the possibility of ambiguity and polysemy is reduced – a machine reader is unable to cope with the idea of interpretation, thus removing a possible impediment to the direct line of causation from the gene-as-data, through its precise and unalterable reading-as-decoding and therefore to its manifestation in the output – the phenotype. If the direct lineage between gene and characteristic implied in the metaphors of language and books is a simplification, then the relationship between computer program and output is even more reductive, decreasing or removing even the (often only latent) possibility of interpretative reading that is inherent in written language.

Thus far, I have described the essential similarity between the language metaphors and those of computer programs. I have argued that while the move from metaphors of language to those of machines, and in particular computers and computer programs, should have entailed an increased complexity in the metaphorical representation of genes, in fact the new metaphors were simply 'upgrades' of the old ones. By this I mean that while the vehicles of these metaphors changed to accommodate technological changes – changes having a profound impact on the practice of science itself – the effects and implications of these metaphors remained the same. However, I will proceed to argue that not only did the shift from the genes-as-language metaphor to the genes-as-computer-program metaphor not provide a more accurate metaphorical scaffold for talking about genetics, but rather this change further entrenched the majority of popular science writing on genetics into a gene-centric position, or at least an interactionism towards the gene-centric end of the spectrum. It did little to encourage the supporters of an environment-centric

[53] Van Dijck, p. 125.

view, and less still to support a 'constructionist interactionism' or complex developmental systems approach such as that of Oyama.

It has long been observed that the history of genetics, in particular of the theorisation of the gene, has resulted in a dual understanding of what a gene is. In his concise history in *The Misunderstood Gene* Michel Morange describes how the gene began simply as a term for hereditary 'factors', and not a material object at all.[54] Indeed, due perhaps to a fear of returning to a preformationist understanding of genetics, there was a resistance to the idea of a physically located 'gene'. Nonetheless, through experimental research, culminating in Watson and Crick's publication in 1953, the location of genes was identified with the chromosomes and then finally with DNA. However, with its localization, the gene did not lose its former sense of the *process* through which transmission of factors took place. Judith Roof has coined the term "DNA gene" to refer to the resulting composite concept: "The two categories – the gene as an organized operation, DNA as a chemical material – have merged conceptually, producing something like a 'DNA gene'".[55] This combining of physical object and the process of transmission is also noted by Evelyn Fox Keller. Arguing that creating a discourse, forging a "way of talking about genes", was of critical importance to the development of genetics, Keller sees the concept of the gene that was created as "part physicist's atom and part Platonic soul – at one and the same time a fundamental building block and an animating force".[56]

I want to argue that the crucial difference between the language-as-gene metaphors and those of computer programs, could equally well be described as the distinction between a "fundamental building block and an animating force". The difference between, on the one hand, the relationship of language to the book or library in which it is contained, and, on the other, of a computer program to the machine that it is housed in, is the same as that between a building block and an animating force – the difference is *agency*. As I have shown, the forms of writing most commonly employed in the language metaphor are instructions, blueprints, recipes: forms that are intended to guide an actor through a prescribed set of actions. But they themselves are not the agent that brings about these actions. This problem, that genes (in a gene-centric argument) apparently carry out the instructions they contain, goes right back to Schrödinger, who believed that "the chromosome structures are [...] instrumental in bringing about the

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54 Michel Morange, *The Misunderstood Gene*, trans. Matthew Cobb (Cambridge, MA: Harvard University Press, 2001) p. 14.

55 Judith Roof, *The Poetics of DNA* (Minneapolis: University of Minnesota Press, 2007), p. 3.

56 Keller, p. 9, p. 10.

development they foreshadow. They are law-code and executive power – or to use another simile, they are architect's plans and builder's craft – in one".[57]

In this way genes are frequently imagined as not just information, but also actors. Coining the term "matter-text", similar to Roof's "DNA gene", Lenny Moss has put it most succinctly, noting that "[i]t is as matter-text that genes and DNA ascend to the status of sentiency and agency, as matter with its own instructions for use, and furthermore, as the user too".[58] He argues that the idea of genes as being both "physical templates for the synthesis of other molecules *and* determinants of organismic traits and phenotypes" requires genes to somehow "provide their own instructions for use" and that it is the idea of "genes being able to do this" that is conveyed in references to "genes as information, as programs, as blueprints, as encyclopaedias of life and the like".[59] Moss is correct to note that these metaphors imply action but these metaphors do not imply that the genes themselves are also the actors – "the user" in Moss's words. This is where the computer program metaphor is critical in the gene-centric representation: computer programs *cause* the set of actions to be performed; they are, if you like, the quintessential performative speech-act, enacting their contents in a way that, perhaps, even Austin's famous examples – bets, weddings, christenings – do not. Perhaps, then, the success of the computer program metaphor is due to the fact that it rhetorically solves Schrödinger's problem – a computer program can almost be "law code and executive power" (programs, after all, are 'executable' files) and imply that genes carry out their own instructions. This hugely simplifies the biology of developmental systems – after all, genes don't themselves 'make' anything, just as Lewontin points out that their 'self-replication' is also reductive: "we do not speak of manuscripts 'self-replicating' in a photocopy machine".[60]

In an oft-quoted passage[61] from *The Selfish Gene* Dawkins describes how proto-genes (what he calls primitive replicators) ended up "safe inside gigantic lumbering robots [...] manipulating [them] by remote-control": the robots he is talking about are "you and me" as well as "all animals, plants, bacteria and viruses" (*SG*, 19-20). In an endnote from the second edition (*SG*, 270-271) Dawkins defends his choice of words, and rightly criticises the authors of *Not In Our Genes* for misquoting his original description: rather than genes that "create us body and mind"

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57 Schrödinger, p. 22.

58 Moss, *What Genes Can't Do*, p. 52.

59 Moss, *What Genes Can't Do*, p. xvii.

60 R.C. Lewontin, Foreword, in Oyama, xii-xiii.

61 For examples, see: Stephen Jay Gould, 'Self-Help for a Hedgehog Stuck on a Molehill', *Evolution*, 51 (1997), 1020-23; Walter Bodmer and Robin McKie, *The Book of Man: The Human Genome Project and the Quest to Discover our Genetic Heritage* (New York: Scribner, 1995), p. viii; R.C. Lewontin, *It Ain't Necessarily So: The Dream of the Human Genome and Other Illusions* (London: Granta, 2000), p. 193; Rose et al., *Not In Our Genes*, p. 287.

(*SG*, 20), they describe genes that "*control* us body and mind" (my emphasis) – a misreading that suits their (rather polemical) criticism of genetic determinism.[62] Despite this, even if the original passage is not so explicit, the misquotation picks up on an implication: the passage *does* contain a sense of the replicators 'controlling' their survival machines from within.

> [W]hat was to be the fate of the ancient replicators? They did not die out, for they are past masters of the survival arts. But do not look for them floating loose in the sea; they gave up that cavalier freedom long ago. Now they swarm in huge colonies, safe inside gigantic lumbering robots, sealed off from the outside communicating with it by tortuous routes, manipulating it by remote control […] they created us, body and mind […] we are their survival machines. (*SG*, 19-20)

It is clear here that the gene is the ontologically prior element – but that is in keeping with Dawkins's theory of genetics. What is more significant is that the gene is also the animate actor in this representation: the organism is a "robot", a "machine" and a "lumbering" one at that. The genes, meanwhile, are described as organism-like, and specifically they might remind us of insects as they "swarm in huge colonies". The genes are the subject of all the verbs in the passage: they 'swarm', 'communicate', 'create' and 'manipulate'.

The implications of this passage are clearly associated with the computer program metaphor. For all Dawkins's observations about robots in his end note, there is little doubt about the common connotations of the word: he asserts that robots "are no longer rigidly inflexible morons", but I believe that the word retains that sense, despite advances in robotics and artificial intelligence. Indeed the epithets "gigantic" and "lumbering" seem to reinforce those stereotypical connotations. As computerised machines, robots require a program to transform them from simply inert electronics, and that program is supplied in Dawkins's image by the genes "safe inside". That we generally consider the machine an inanimate container for the animating program is obvious from the terms such as 'computer virus', 'worms', or a 'bug' that have crossed over from biology to computer programs.

In this way genes are metaphorically figured as the animating program inside the passive container of the body. This agency attributed to genes is the crucial difference that makes the 'upgraded' metaphors of genes as computer programs even more powerfully suggestive of their determination of an organism's behaviour. Language 'makes up' the contents of a book; it is, to

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[62] Rose et al., *Not In Our Genes*, p. 287. Lewontin also reproduces the misquotation in: *It Ain't Necessarily So* on p. 193; R.C. Lewontin, *Human Diversity* (San Francisco: Scientific American, 1982), p. 18; R.C. Lewontin, 'The organism as the subject and object of evolution', *Scientia*, 118 (1983), 65–82, (p. 68); R. Levins, & R.C. Lewontin, *The Dialectical Biologist* (Cambridge, MA: Harvard University Press, 1985), p. 88 and p. 128.

use another image that is almost demetaphorized and to which I will turn in a moment, the 'building blocks' from which a book is 'constructed'. Computer programs, however, govern the *behaviour* of the machine in which they are run. This difference is analogous to a distinction between genes controlling the construction of organisms (their responsibility for physical phenotypic characteristics) and genes controlling the behaviour of the organism: the distinction, exactly, between 'creating us body and mind' and 'controlling us body and mind'.

5.1.3 Building a Body, Baking a Body

The dynamics that I have already identified in the metaphors of language and computer programs are also present in the popular metaphor of the genes as a 'blueprint' for 'building' a body: I have argued that the presentation of the genome as a set of instructions, either in natural language or in computer code, is reductive in the specific sense that it implies a simplified relation between the genes and their phenotypic manifestation: that the 'meaning' 'encoded' in the genes is simply 'read' off them without reference to environmental conditions. The metaphor of the genes as a blueprint works in the same way; I would argue that, indeed, the potential for polysemy in the diagrammatic blueprint metaphor is *less* than in the language or computer program metaphor. In this way, 'blueprint' metaphors are even more strongly suggestive of genetic determinism. In addition, since the building that is produced is little more than a scaled-up, three-dimensional version of that represented in the blueprint, this metaphor is suggestive not only of the unambiguous progress from genotype to phenotype, but also strongly implies a preformationist and atomistic perspective.

The blueprint/building metaphor also raises some of the same issues as that of the computer program in that it locates the agency of the development of the organism in the genes. The association between this metaphor and this problem is already present in Schrödinger's comparison, "the chromosome structures are [...also] instrumental in bringing about the development they foreshadow [...] they are architect's plans and builder's craft".[63] Oyama has turned this simile around in a concise criticism of the blueprint metaphor: "Though a plan implies action, it does not itself act, so if the genes are a blueprint, something else is the contractor-construction worker".[64] Her conclusion is that the blueprint metaphor is not intended

63 Schrödinger, p. 22.
64 Oyama, p. 54.

"to *illuminate* developmental processes, but rather to *assume* them and [...] to impute cognitive function to the genes".[65]

In the building metaphor, then, the genes/DNA act as both architect and the builders of the body and are animate in a way that the building that is produced is not. In an extended metaphorical description in Richard Pollack's *Signs of Life*, the division of a cell is imagined as one of the two World Trade Center towers copying itself to make a matching second tower.[66] This description emphasises on the one hand the animation/vivacity of the processes involving DNA, whilst on the other the building itself is conspicuously inanimate. The building represents a cell, not a body; but nonetheless the contrast between the descriptions is sharp. The tower is described passively: it is "anonymous, filled with endless offices [...] brightly lit, well vented"; "pipes bring in and take out the necessary fluids, energy and heat"; the only active verb the buildings are ascribed is that "[they] vent their excess heat".[67] Whilst the activity surrounding the building is emphasised – "[p]rodigious numbers of people and vast amounts of information and money move in and out of these buildings" – they themselves "remain, quite unperturbed, much as they were on the day they opened".[68]

When we – the passage is addressed to the reader – enter the single WTC tower, the building is apparently lifeless: there are "corridors, elevators and such", but there is no mention or implication of animation. Until, that is, we enter "the central core of the building".[69] Here, activity is constant, and present participles proliferate:

> personnel scurry back and forth [...] carrying sheaves of computer printouts. It is not at all clear what work they are performing [....]
>
> Officious staff are carefully taking down one or another volume, photocopying an article, and replacing the volume. These clerks come and go, carrying out photocopies of pages [...] and coming back with instructions for more copies.[70]

As the cell is about to divide, the "library staff is suddenly excited; some are scurrying out of the library". The cell division itself, however, located as it is on the scale of the cell – part of the machine not the program – is a surprisingly passive event. Presaged by a mere "soft vibration"

65 Oyama, p. 54-55.
66 Pollack, pp. 15-17.
67 Pollack, p. 15.
68 Ibid.
69 Pollack, p. 16.
70 Ibid.

the tower splits "quite smoothly and silently"; "no one [...] seems to find anything unusual about this quiet, massive, precise doubling".[71]

Whilst the blueprint metaphor is a very common one in popular science on genetics, some writers have prominently questioned its usefulness, and identified some of its problematic implications. In *Nature via Nurture* Matt Ridley notes early on that "[g]enes are not puppet masters; nor blueprints [...] Somehow the adherents of the 'nurture' side of the argument have scared themselves silly at the power and inevitability of genes"; more significantly for my argument, however, he reminds us, in an image that recalls the importance of developmental or ontogenetic processes, that "bodies are not made, they grow".[72] Instead of the blueprint metaphor Ridley chooses a different sort of text:

> The genome is not a blueprint for constructing a body; it is a recipe for baking a body. The chicken embryo is marinaded for a shorter time in the Hoxc8 sauce than the mouse embryo. This is a metaphor I shall return to frequently in the book, for it is one of the best ways of explaining why nature and nurture are not opposed to each other, but work together.[73]

The shift from a concrete fixed blueprint to the slightly more fluid textual instruction of a recipe does indeed suggest a greater emphasis on environment. Rose, Lewontin and Kramin in their critique of genetic determinism, *Not In Our Genes*, employ the same image, though in their more *gestalt* equivalent the emphasis is entirely upon the idea of baking as a process: they ask us to "[t]hink, for example, of the baking of a cake". The cake, they argue "is the result of a complex interaction of components – such as butter, sugar, and flour – exposed for various periods to elevated temperatures".[74] The deliberate vagueness of the constituent ingredients, and of their quantities and of the length and temperature of cooking, all deny this image any association with a recipe or set of instructions, whilst the emphasis on the combination and interaction of ingredients and on temperature, all emphasise the role of environment: the ambiguity about the baking process suggests the limits, in line with their stated agenda, of genetic determinism.

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71 Pollack, p. 16, p. 17.

72 Ridley, *Nature via Nurture,* p. 6, p. 32.

73 Ridley, *Nature via Nurture*, p. 32. Although Ridley is employing this hox gene scenario as an example of a non-determinist interactionism between genes and environment, the extent to which this emphasises environmental factors is somewhat doubtful – the hox genes are expressed for longer or shorter periods depending on 'promoters', which are sections of the DNA. Although not normally called 'genes' themselves, they are definitely genetic and not environmental. A fly, despite having the same hox gene as a mouse, will not turn into a mouse depending on environmental conditions, but on its gene promoters located on its DNA.

74 Rose et al., *Not In Our Genes*, p. 11.

Dawkins, in his scathing review of *Not In Our Genes*, uses this very passage to argue that the targets of that book – supposed genetic determinists – are "not quite the naively atomistic reductionists they [Rose et al.] would desperately like them to be": the image of the cake, he notes, was one that he himself had used to reveal the flaws in genetic atomism.[75] Elsewhere, in *The Blind Watchmaker*, Dawkins has shown an even more specific awareness of the problems of the blueprint metaphor, and the (relative) benefits of the recipe metaphor, recognising in particular the preformationist implications of the blueprint metaphor:

> Modern preformationism – the blueprint theory – holds that the DNA in a fertilized egg is equivalent to a blueprint of the adult body. [...] Each bit of the blueprint corresponds to a matching bit of the building. There is a sense in which the blueprint is a miniaturized 'preformed' building[.] (*BW,* 294-295)

This pitfall, Dawkins shows, is avoided by the recipe metaphor, since "a recipe is not a scale model, not a description of a finished cake, not in any sense a point-for-point representation. It is a set of instructions which, if obeyed in the right order, will result in a cake" (*BW*, 295). It is interesting to note that the recipe metaphor does lead Dawkins closer to a constructivist-interactionist description of development, noting that the phenotypic expression of genes is highly dependent on the conditions during development:

> the effect that a gene has when it *is* turned on depends upon what there is, in the local part of the embryo, to have an effect on [...] So, the effect, if any, that a gene has is not a simple property of the gene itself, but is a property of the gene in interaction with the recent history of its local surroundings in the embryo. (*BW*, 296)

Despite this it is important to observe that as Dawkins continues with the recipe analogy, the factors that he describes as resulting in differences in the cake are all differences to the original recipe (the substitution of an ingredient, a change in oven temperature); they are not, to continue within the frame of the cake metaphor, differences in the kitchen in which the cake is baked, or the style of oven used, or the origin of the ingredients used, or the temperature of the cook's hands, and so on. This still places the emphasis for differences in the organism ('cake') in the DNA ('recipe'). Indeed, it is significant that the metaphor as Dawkins uses it here is very much the 'recipe metaphor'; the emphasis is definitely placed on the recipe, not on the *process* of baking. As a point of contrast, Rose et al. do not, in their cake baking analogy, mention a recipe at all.

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[75] Richard Dawkins, 'Sociobiology: The debate continues', review of Rose, Lewontin & Kamin, *Not In Our Genes* in *New Scientist*, 24 January 1985, 59-60 (p. 60).

The very similar exposition of the blueprint/recipe metaphor comparison in *The Devil's Chaplain* exhibits the same emphasis on the recipe – the preformationism of information, as Oyama would observe. Here, Dawkins again observes that you cannot map a recipe to a dish, point for point – nor can you reconstruct the recipe from the dish:

> A blueprint is a detailed, point-for-point specification of some end product like a house or a car. [...] Give an engineer a car and he can reconstruct its blueprint. But offer to a chef a rival's *pièce de resistance* to taste and he will fail to reconstruct the recipe.[76]

This difficulty in reconstructing the recipe from the dish shows that the recipe metaphor, unlike the blueprint metaphor, is non-reversible. This is an important distinction for Dawkins's argument because the impossibility of moving from the dish to the recipe (from the organism back to the genes) describes the impossibility of inscribing acquired characteristics in the genes, and therefore the impossibility of inheriting these acquired characteristics. In other words, the move from the blueprint to the recipe metaphor is a necessary one in avoiding the suggestion of Lamarckism. The reason that he gives for this non-reversibility is that the interaction of the elements specified in the recipe make the reconstruction impossible: but this ignores the other essential element that impedes reconstruction of the recipe from the dish – the variability of environmental conditions under which the recipe was carried out.

* * * *

It is not my intention, in this analysis, to claim that the writers quoted here explicitly support, to a greater or lesser degree, a form of genetic determinism. Indeed, many of the authors are keen to stress the problems with genetic determinism and assert their adherence to a more balanced form of interactionism. My examination of the presentation of genetics is concerned more with showing how a rhetoric of gene-centrism has become both pervasive and entrenched. Nevertheless, this does not mean that these writers are not caught up in describing a 'conceptually vacuous' form of interactionism of the kind that Oyama rightly criticises; nor does it mean that their gene-centric rhetoric does not lead them into suggestions of determinism even as they deny them.

The description of genes via a metaphor of language has a long pedigree, pre-dating even the discovery of DNA. However, I have shown how the common form of the metaphor in popular science writing on genetics associates genes with physically locatable textual instructions or

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76 Richard Dawkins, *A Devil's Chaplain: Selected Essays* (London: Weidenfeld & Nicolson, 2003), p. 105.

information, and in so doing shuts down the potential polysemy of language, in particular its dependence on context. The result is a metaphor that suggests the directness of the connection between genes and their manifestation in the phenotype. This same emphasis can also be seen in the similar set of computer program metaphors; indeed, I argue that the potential for multiple meanings and context-dependence is excluded to an even greater degree in computer program metaphors. Furthermore, these metaphors locate an important part of the agency of the organism in the genes: just as software does not simply provide instructions but in some way also *causes* actions, so, it is implied, genes are also in some way the actors that create and govern a body. The genes become an updated homunculoid.[77]

Dawkins's own criticisms of the blueprint metaphor reveal that he recognises the problems of the preformationism inherent in that particular pedagogic metaphor. Replacing it with the metaphor of a recipe may reduce or even remove some of the preformationist implications, and it certainly in its non-reversibility removes the possibility of the inheritance of acquired characteristics; but an emphasis on the recipe, the set of instructions that produce the cake, rather than on the process of making the cake and the environmental context in which the cake is made, maintains a strong gene-centric perspective. Although recipes are not one of the metaphors that Oyama identifies in *The Ontogeny of Information*, Dawkins's replacement of blueprints with recipes is a perfect example of the form of interactionism that she criticises – it sees development as just "encoded nature with varying doses of contingent nurture".[78] Furthermore, the recipe itself is a good example of the tendency to simply transfer the preformationism to some concept of 'information', and as such is no improvement on the blueprint metaphor.

In the Afterword to the second edition of *The Ontogeny of Information*, Oyama notes that the asymmetrical application of mentalistic language in descriptions of genetics creates difficulties, "perhaps even feeding a subtle biological determinism that the analysts themselves may try to disavow".[79] It has been my intention in this chapter to show that these dynamics are in play in the use of metaphors of language, of computer programs and of blueprints and recipes. In the next chapter, I will show that similar problems arise in popular discourse around evolutionary biology: in particular, that the use of certain metaphors and the construction of narratives can reinstate into popular science texts a form of determinism – a teleological view of evolution – that their authors would expressly deny.

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77 Oyama, p. 54.
78 Oyama, p. 5.
79 Oyama, p. 201.

5.2 Evolutionary Determinism

There is a tendency, one born of human arrogance, to see the development of our own species as the pinnacle of the process of evolution. In the Prologue to his book of essays *Ever Since Darwin* (1980), Stephen Jay Gould quotes from the essay in which Freud argues that the implications of Darwin's theory of evolution, as set forth in *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, represented one of the three fundamental 'blows' or 'wounds' that man has suffered to his "self-love".[80] The first of these, the cosmological blow, Freud assigns to Copernicus, a result of undermining the dominant view of the universe with the earth at the centre; the "third blow, which is psychological in nature", he reserves for his own work, a consequence of the revelation that "*the ego is not master in its own house*".[81] It is the second blow, "the biological blow to human narcissism", that Freud attributes to Darwin's theory for putting "an end to this presumption on the part of man" that he is "a being different from animals or superior to them".[82] Whether or not one agrees with the wider claims of Freud's (far from humble) assessment, it is undeniable that this implication of Darwin's work – the de-centring, or demoting of man from his position of superiority – was a major cause of the outcry over the *Origin of Species* on its publication and a factor in the subsequent one hundred and fifty year backlash against the theory and its successors.[83]

Gould, however, "submit[s] that the knowledge of this relegation [from having been specially created to being a descendant from the animal world] is also our greatest hope".[84] Both Gould and Richard Dawkins repeatedly criticise the anthropocentric attitude that places man at the centre of the natural order, or at the 'top', or sees man as the culmination of evolution's 'progress'. In *River Out of Eden* (1995), for example, Dawkins follows a brief description of insects' perception of "flicker" by observing that "[t]he world as seen through an insect's eyes is so alien to us that to make statements based on our own experience when discussing how 'perfectly' an orchid needs to mimic a female wasp's body is human presumption" and warns that "we must beware of using human intuition" when thinking about evolutionary adaptation.[85]

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80 Sigmund Freud, *The Standard Edition of the Complete Psychological Works*, trans. and ed. by James Strachey, 24 vols, (London: Hogarth Press, 1953-74), XVII, 143.

81 Ibid.

82 Freud, p. 141.

83 This backlash continues unabated. Witness the recent (March 2009) revival of the debate over the teaching of evolution by the Texas School Board.

84 Stephen Jay Gould, *Ever Since Darwin: Reflections in Natural History* (Harmondsworth: Penguin, 1980), p. 17. All subsequent references are to this edition, hereafter *ESD*, and will be made in the text.

85 Richard Dawkins, *River Out of Eden* (New York: Basic Books, 1995), p. 66, p. 67. All subsequent references are to this edition, hereafter *RE*, and will be made in the text.

Similarly, Gould, in the opening chapter of *Life's Grandeur* (1996), criticises our anthropocentric tendencies through an analysis of the "iconographic tradition of painting successive scenes to illustrate the pageant of life through time":[86]

> The last few paintings always depict humans, even though we are but one species in a small group of mammals [...] while the greatest successes of mammalian evolution – bats, rats, and antelopes – remain invisible. [...] If these pageantries only claimed to be illustrating the ancestry of our tiny human twig on life's tree, then I would not complain[;] (*LG*, 14)
>
> much as we may love ourselves, *Homo Sapiens* is not representative, or symbolic, of life as a whole. We are not surrogates for arthropods [...] or exemplars of anything either particular or typical. (*LG*, 15)

However, despite this criticism of anthropocentrism we see that the exclusion of man from these texts is impossible. We can compare this with Gillian Beer's observation, in her seminal work *Darwin's Plots*, that there is in Darwin's treatise an ostensible removal, an absenting, of man; man is not the subject of the *Origin*, and this fact undermined the prevailing contemporary conception of man as the centre of the natural world. In a chapter entitled 'Fit and Misfitting: Anthropomorphism and the Natural Order', Beer argues that Darwin deliberately downplayed the implications of his theory for man's position in the natural world by excluding man from the text of *The Origin*:

> Man is a determining absence in the argument of *The Origin of Species*. In the first edition he appears only once as the subject of direct enquiry; that appearance is in the Conclusion of the work and is cast in the future tense. [...] Any enquiry into the implications for man of Darwin's ideas is held beyond the bounds of the text. (*DP*, 58-9)

Citing letters from Darwin to Wallace and Jenyns that reveal that Darwin intended to "avoid the whole subject [of man]", Beer notes that "the avoidance of the topic of man is, according to Darwin, tactical" (*DP*, 59) and argues that it is this absence, and hence the implied demotion of man from his position at the pinnacle of a hierarchy of plant and animals kingdoms, that made *The Origin* "deeply disquieting": "The absence of any specific reference to man as the crowning achievement of the natural and supernatural order made the text subversive" (*DP*, 60). Removing man formed part of Darwin's attempt "to subdue the hierarchical nature of man's thought which places himself always at the pinnacle or centre" (*DP*, 60).

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[86] Stephen Jay Gould, *Life's Grandeur: The Spread of Excellence from Plato to Darwin* (London: Vintage, 1996), p. 9. All subsequent references are to this edition, hereafter *LG*, and will be made in the text.

The inherent anthropocentrism of language, however, precludes the complete exclusion of man. Beer argues that despite Darwin's "decision to exclude man from his discussion" (*DP*, 61), man is present in the text, and not merely as an inevitable consequence of the fact that, as she has identified elsewhere, "writing is itself the inscription of human distinctiveness".[87] Darwin effects a strategic re-insertion of man that does not involve a re-centring, but ranges man alongside all the other forms of life, supporting Darwin's view of man's kinship with the rest of the natural world. Certainly for Beer, "language is anthropocentric, persistently drawing the human back to the centre of meaning",[88] but the presence of man in *The Origin* is more strategic than this: "man is a familiar in *The Origin* though concealed in its interstices" (*DP*, 61). Beer believes this concealment to be deliberate and strategic: "Without his [Darwin's] analysing or needing to analyse his reasons, therefore, there seem to have been as good social as there were religious reasons for Darwin to attempt to conceal man in the interstices of his text" (*DP*, 63).

Man may never be the subject of enquiry in *The Origin*, but he is frequently present as "the second term in metaphors" (*DP*, 60). The metaphorical yoking of the animal kingdom with man implies the continuum between the two that was central to Darwin's theory. Beer asks "Is the sub-text of *The Origin* simply unavoidably full of human reference (because cast in human language) or is it knowingly, even strategically, so? And if so, to what ends?" (*DP*, 62). Clearly for Beer this sub-text *is* strategic; through such references Darwin "sought to restore man to his kinship with all other forms of life" (*DP*, 63).

Just as in *The Origin*, man is present in popular science accounts of evolution, such as those of Dawkins and Gould, in the form of anthropomorphic metaphors. The suggestion of consciousness and motive, which I will term 'intentionalism', involved, for example, in describing genes as 'selfish', draws man back to the centre of meaning.[89] The significance of this re-centring of man is that, as we shall see, this is part of a larger representation of evolution as essentially teleological or progressive: man comes to be figured as the end-point or goal of evolution, a fact that lends to the process of evolution a suggestion of inevitability. That anthropocentrism identified by Freud – the human arrogance that sees man as the pinnacle of evolution – has deep roots, and is not weeded out by Darwin's intervention.

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87 Beer, *Open Fields*, p. 155.

88 Ibid.

89 It is ironic that Dawkins's own concerns over the accuracy of the title focus rather on the concept of the gene, vaguely "defined as a piece of chromosome which is sufficiently short for it to last, potentially, for *long enough* for it to function as a significant unit of natural selection" (*SG*, 36). Suggesting alternative, more accurate titles, Dawkins revises this word, but the word 'selfish' remains: "To be strict, this book should be called not *The Selfish Cistron* nor *The Selfish Chromosome*, but *The slightly selfish big bit of chromosome and the even more selfish little bit of chromosome*. To say the least this is not a catchy title." (*SG*, 33).

Despite Dawkins's deliberate attempts to distance himself from literal readings of the phrase 'selfish gene', reviewers have been struck by the intentionalism of Dawkins's title.[90] Mary Midgley memorably opened her polemical review of Dawkins's book by announcing that "[g]enes cannot be selfish or unselfish, any more than atoms can be generous, elephants abstract, or biscuits teleological".[91] Midgley's review is more sophisticated than many, and the objection to the idea of 'selfish genes' is not a mistaken literal reading but rather, as she explains in a later article, an objection to the use of "the term *selfish* [...] which centres its normal meaning on motive, not on a fixed range of acts".[92] She cites Dawkins's defence that "it [the word 'selfish'] is, he says, a harmless, well-known technical term" used in a "special, restricted sense" but she objects that "a *restricted* sense ought to be one which forms part of the normal meaning of the word. It cannot be one which falls, as this does, right outside it".[93]

Her objections, as she realises, should be aimed more generally than simply at Dawkins: "this question should be put to a whole school of biologists".[94] But even this is not broad enough – for the problem of language that is suggestive of motive, intention or consciousness is pervasive throughout the sciences. In his defence of metaphorically intentionalist language Dawkins could have legitimately quoted Darwin's response, from the Preface to the third edition of *The Origin*, to similar criticism:

> In the literal sense of the word, no doubt, natural selection is a misnomer; but whoever objected to chemists speaking of the elective affinities of the various elements? – and yet an acid cannot strictly be said to elect the base with which it will in preference combine [...W]ho objects to an author speaking of the attraction of gravity as ruling the movements of the planets? Everyone knows what is meant and is implied by such metaphorical expressions; and they are almost necessary for brevity.[95]

The phrase 'natural selection' is indeed a misnomer, pulling in two directions simultaneously: the word 'selection' implies consciousness, an implication that is counteracted, but not eradicated, by the word 'natural'. The image of a "Blind Watchmaker", used in another Dawkins title, reveals a similar dynamic – the consciousness implied by the image of a watchmaker is not really negated by the fact of his blindness. In *The Blind Watchmaker*, Dawkins opens a chapter with a discussion

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90 See *SG*, 47 and 50-1; and *UR*, 189.
91 Mary Midgley, 'Gene-Juggling', *Philosophy*, 54 (1979), 439-58, (p. 439).
92 Mary Midgley, 'Selfish Genes and Social Darwinism', *Philosophy*, 58 (1983), 365-77, (p. 367).
93 Ibid.
94 Ibid.
95 From Darwin's Preface added to the 3rd Edition. Charles Darwin, *The Origin of Species: A Variorum Text*, ed. by Morse Peckham (Philadelphia: University of Pennsylvania Press, 1959), p. 165.

of the Argument from Good Design, beginning: "Natural selection is the blind watchmaker, blind because it does not see ahead, does not plan consequences, has no purpose in view". (*BW*, 24) There are considerable problems with a rhetoric that rejects the Argument from Intelligent Design, replacing the intelligent designer with the process of natural selection, but in doing so re-associates this non-conscious process with a conscious designer through the metaphor of the 'blind watchmaker'; and not just any conscious designer – the image of the watchmaker, of course, is from Paley's *Natural Theology* (1802), the most well known exposition of the Argument of Good Design.[96] Put simply, just as 'natural' does not remove the idea of intention inherent in 'selection', the modifying adjective 'blind' does not remove the element of consciousness. But beyond the attribution of consciousness there is here an additional element of anthropocentrism, as the metaphorical creator or designer in this case is not a deity, but a 'watchmaker'; in this metaphor the creator, natural selection, is cast in man's image. Man is not merely reinstated as at the centre of God's creation, but is imaged as the creator himself.

Unlike in Darwin's *Origin*, it is not left to anthropomorphic metaphors to reintroduce man into Dawkins's and Gould's texts; man is also more explicitly reinserted. He is present not merely as the second term in metaphors, but also as a direct subject of enquiry. Both writers follow Darwin in their rejection of anthropocentrism; but unlike Darwin, man, far from being a 'determining absence', is instead a determining presence. The explicit aim of their books is to expound a particular element or reinterpretation of evolutionary theory; but the subsequent application of theory to the specific case of humankind is an important element in both writers' works. It is tempting to speculate that whilst Darwin removed man as the subject of enquiry in the *Origin* to shift the focus away from some of the controversial implications of his theory, man is implicitly the subject of most current popular science writing in the field of evolutionary biology precisely *because* the application of evolutionary theory to man seems controversial, and is therefore more marketable.[97] Dawkins's final chapter of the 1976 edition of *The Selfish Gene*, in which he coins the term 'meme' for the cultural equivalent of a gene, begins "[s]o far, I have not talked much about man in particular, though I have not deliberately excluded him either"; he goes on to apply the theory of gene-level selection, elaborated in the previous chapters, to culture, the one thing that, for Dawkins, "is unusual about man".[98] In the last chapter of *River Out of Eden* Dawkins again

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96 William Paley, *Paley's Watchmaker: An Abridged Version of William Paley's Natural Theology*, ed. and intro. by Bill Cooper (Chichester: New Wine Press, 1997).

97 That there is this correlation between controversy and publishing success is difficult to prove, but the blurb for the Penguin edition of *The Blind Watchmaker*, for example, advertises the book as "brilliant and controversial". Similarly, it is conspicuous that Penguin chose for the front of *Wonderful Life*, a book primarily about palaeontology and the Burgess Shale, an excerpt from the *Sunday Times* review that describes the book as "a milestone in man's view of himself".

98 Richard Dawkins, *The Selfish Gene* (Oxford: Oxford University Press, 1976), Ch. 11.

turns his attention more explicitly to man, briefly discussing various cultural 'thresholds' such as the "Language Threshold", "Cooperative Technology Threshold", "Radio Threshold" and "Space Travel Threshold" (*RE*, 157-160). Similarly, Gould in *Life's Grandeur* proposes a general model for "view[ing] trends in an entirely different way: as changes in variation within complete systems" (*LG*, 1), and then applies this model to two examples: one is the "resolution of the problem of progress in the history of life" (*LG*, 2); the other the unashamedly anthropocentric (not to say nationally specific – Gould includes "A Baseball Primer for British Readers") subject of "the disappearance of 0.400 hitting in baseball" (*LG*, 1).

This tendency to explicitly elucidate the implications for mankind of any specific aspect of evolutionary theory can be seen as moving towards the anthropocentrism which Dawkins and Gould criticise in, say, iconographic representations of evolution. It is an understandable tendency: readers want to read about their own origins. It has been observed that popular science books on cosmology and evolutionary biology outnumber those on other fields because they purport to explain the origins of, respectively, the universe and life on earth – and therefore also to explain our own existence. Again, savvy publishers are aware of this: the back cover of the Harper Perrenial edition of Matt Ridley's *Nature via Nurture* carries the question "What makes us who we are?" in large letters; the blurb for *The Blind Watchmaker*, already cited, ends with "the biggest question of all: why do we exist?" (*BW*, back cover); the first chapter of Dawkins's *The Selfish Gene* is entitled "Why are people? (*SG*, 1); and both the blurb and chapter headings of Johnjoe McFadden's *Quantum Evolution* are replete with such rhetorical questions – "How did life start?", "How did we get here?", "What does it all mean?".[99]

The reinsertion of man back into the popular accounts of Dawkins and Gould, both explicitly as the subject of enquiry and also through anthropomorphic metaphors, can be seen as working against the resistance on the part of both Dawkins and Gould to the idea of 'progressive' evolution. Both writers explicitly, and frequently, dismiss the idea of progressive evolution in the sense of improvement through evolutionary time. This rejection of progressive, teleological evolution requires the demotion of man from his perceived position at the end or peak of evolutionary improvement, but the presence of man in these texts implies his continuing centrality. In the next section I will examine in more detail this resistance to a teleological bias, and will argue that despite a conspicuous denial of teleology, a process of exclusion and reinstatement is again at work: just as man re-enters the texts despite attempts to resist an

[99] Ridley, *Nature via Nurture*, back cover; Johnjoe McFadden, *Quantum Evolution* (London: HarperCollins, 2000), inside front cover, Chapter 4 title, Chapter 9 title.

anthropocentric perspective, so the notion of progress evolution re-asserts itself despite the rejection of a teleology of evolutionary improvement.

5.2.1 Teleology

Gould dedicates one of his essays in his collection *Ever Since Darwin* to a discussion of iconographies of evolution: the popular conception of gradual evolutionary progress as a 'ladder', to which he opposes his own view of evolution based on rapid, possibly allopatric, speciation followed by decimation or mass extinction, a process that he images as a 'bush'. His point, made in reference to the problem of reconstructing the evolution of modern man, is a resistance to the notion of evolutionary 'progress':

> Evolution usually proceeds by 'speciation' [...] not by the slow and steady transformation of these large parental stocks. Repeated episodes of speciation produce a bush. Evolutionary 'sequences' are not rungs on a ladder, but our retrospective reconstruction of a circuitous path [...] from the base of the bush to a lineage now surviving at its top (*ESD*, 61)

Gould elaborates on this short essay in the first chapter of *Wonderful Life*, entitled 'The Iconography of an Expectation', examining images of the 'march of progress' associated with the gradual and progressive 'ladder' view of evolution and also the classic image of the 'tree of life'.[100] Both systems of iconography, Gould contests, are "chosen to validate our hopes of predictable progress": the 'march of progress' clearly depicts the gradual improvement of life towards its culmination, man; likewise, the "conventional iconography [of the tree of life] has fastened upon a primary model, the 'cone of increasing diversity', an upside-down Christmas tree. Life begins with the simple and progresses ever upward to more and more and, by implication, better and better" (*WL*, 38). Gould isolates more precisely the slippage in the 'cone of increasing diversity' as a conflation of meanings: the vertical axis on a cone ostensibly represents time, but "we also read upward movement as simple to complex, or primitive to advanced" (Ibid.).

Although it is Gould who is frequently held up, and as frequently holds himself up, as a representative of this view of non-progressive evolution (possibly because of confusion with Gould's origination of the idea of evolution as non-*gradual*, what he and Eldredge termed

[100] Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (Harmondsworth: Penguin Books, 1991), chapter 1. All subsequent references are to this edition, hereafter *WL*, and will be made in the text.

'punctuated equilibrium'),[101] this resistance is present from the beginning of evolutionary theory. Darwin struggled with it, writing a note in his copy of Robert Chambers's *The Vestiges of Creation* reminding himself to "Never use the words 'higher' and 'lower'", and so identifying the same connotations of the vertical hierarchy as Gould.[102] Dawkins similarly rejects the idea of evolutionary 'improvement', concisely noting in *The Blind Watchmaker* that "[l]ife isn't like that. Evolution has no long-term goal. There is no long-distance target, no final perfection to serve as a criterion for selection, although human vanity cherishes the absurd notion that our species is the final goal of evolution" (*BW*, 61). This observation also shows clearly the connection between the teleology of progress, the perception of a "long-term goal" for evolution, and the "human vanity" of anthropocentrism; the obverse of this is that the re-centring of man in popular biology texts is an important part of the reinstatement of a teleology of evolution.

Earlier in this chapter I argued, quoting from *The Blind Watchmaker*, that there were problems with denying the Argument from Intelligent Design with an anthropomorphic metaphor that brings into presence the very conscious and intelligent designer Dawkins seeks to deny. Returning to this sentence – "Natural selection is the blind watchmaker, blind because it does not see ahead, does not plan consequences, has no purpose in view" (*BW*, 24) – it is clear that there is an even more striking problem in terms of Dawkins's rejection of a teleology of evolutionary progress. The combination of the blindness of the watchmaker and the (dead) metaphors of vision for forward planning – "see ahead", "purpose in view" – result in the desired implication that natural selection does not plan ahead. But this does not remove the fact that a watchmaker, blind or otherwise and unlike natural selection, does have a "purpose", does "plan consequences", does (to use another metaphor of vision) have foresight. Paley chose his example well: purpose is inherent in the example of the watchmaker – the purpose of a watchmaker is, quite simply, to make watches. In other words, the watchmaker literally 'embodies' the idea of improvement or progress. Just as anthropomorphic metaphors re-centre man despite the criticism of the anthropocentric perspective, so here the metaphor works against the explicit statement of the non-purposiveness of evolution. The image of the watchmaker at least partially reinstates the notion of design and purpose and thus a teleology of increasing perfection.

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101 N. Eldredge and S.J. Gould, 'Punctuated Equilibria: An alternative to phyletic gradualism' in *Models in Paleobiology*, ed. by T.J.M. Schopf (San Francisco: Freeman Cooper, 1972) pp. 82-115.

102 Quoted in J.W. Burrow's introduction in *The Origin of Species*, ed. and intro. by J.W. Burrow (Harmondsworth: Penguin Classics, 1968), p. 33. Beer notes that Darwin records the same resolution in his notebooks (*DP*, 61).

If metaphors may – but do not necessarily – imply the idea of progress towards an end goal, then narrative, almost by necessity, does.[103] Narrative normally contains not simply the idea of progress in the sense of "Motion forwards, as opposed to rest or regress; advance" but the sense of progress towards an end point.[104] As a narrative develops "the choices become more and more limited and the final choice seems not a choice at all but an inevitability".[105] The paradigmatic example is detective or mystery fiction – which, interestingly, often provides a model for popular science writing: to borrow the rhetoric of Good Designers, detective stories reveal the existence of a designer.[106] I want to examine here one particular narrative often constructed by popular science writers, and interesting in its own right, but one that can also be seen to play an important part in suggesting the inevitable progress of evolution in the texts I have already examined in this section.

Ron Curtis, in his article 'Narrative Form and Normative Force: Baconian Story-telling in Popular Science', sees a "close formal analogy between the narrative of resolution and this method [of induction by elimination]", and argues that the construction of narratives in popular science writing "is a way to moralize while appearing only to describe": as the writer's "interpretation and emplotment slips out of notice, so also – if to narrate is to moralize – do his normative judgements, which are therefore not readily open to criticism".[107] The result is that "only one theory of science [Baconian induction by elimination] is readily but tacitly expressed and endorsed, not only to a popular audience but also as part of a continuing debate among scientists themselves".[108] A normative account or science is written into these narratives.

It is this normative narrative of scientific discovery that I would like to examine, an account that presents the cumulative, progressive and improving state of scientific knowledge. However, my argument goes beyond that presented by Ron Curtis: I argue that this normative narrative of science represents a teleology of progress that, in popular science writing on evolutionary theory, takes the place of and is conflated with evolutionary adaptation. Science becomes an end-point of evolutionary progress. The popular science books that I focus on construct normative narratives

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103 Abbott, p. 41.

104 progress, n., 6.c, *Oxford English Dictionary*, 2nd edn, 1989, *OED Online*, Oxford University Press <http://dictionary.oed.com/cgi/entry/50189648> [accessed 01 July 2010].

105 S. Chatman, *Story and Discourse: Narrative Structure in Fiction and Film* (Ithaca, NY: Cornell University Press, 1978), p. 85. Quoted in R. Curtis, 'Narrative Form and Normative Force: Baconian Story-telling in Popular Science', *Social Studies of Science*, 24 (1994), 419-61 (p. 431).

106 Cf. Leane, Chapter 6; Curtis, pp. 435-441. Note too the formal similarity between Dawkins's titles (*The Selfish Gene*, *The Blind Watchmaker*, *The Ancestor's Tale*, *The God Delusion*) and classic generic detective fiction titles (*The Third Man*, *The Ipcress File*, *The Maltese Falcon*, *The Bourne Identity*).

107 Curtis, p. 431, pp. 434-5.

108 Curtis, p. 419.

of scientific discovery; but they also isolate the idea of scientific self-knowledge as a *telos* of the progression of both scientific discovery and also, by a fundamental slippage, of evolutionary progress. The two systems are conflated and the teleology of scientific progress – which ends with self-knowledge and that particular form of self knowledge that is awareness of our own origins, the discovery of evolutionary theory – is exported back into the realm of evolutionary theory itself.

Of course, to a degree, this normative narrative of scientific discovery can be identified in professional science writing as well as in popular science writing. On the level of both individual 'discoveries' and also on the larger scale of the history of scientific progress, both popular and professional science writing is frequently involved in the construction of a linear narrative of progress. Peter Medawar has observed that "the scientific paper is a fraud in the sense that it does give a totally misleading narrative of the processes of thought that go into making a scientific discovery".[109] Greg Myers, in a chapter entitled 'Making a Discovery: Narratives of Split Genes', focuses on how a "discovery narrative" enters into popular interpretations of scientific research, "between texts, in the interpretation of one text by another, as a process of reading as well as writing", creating a story with an easily identifiable 'eureka moment'.[110] Myers takes it for granted that a level of narrative distortion has already taken place by the time of the scientific paper: "It doesn't worry me here that all research reports are idealized versions of what went on in the lab".[111] The initial distortion is a movement away from a narrative of discovery, removing essential narrative elements – historical chronology, actors, and audiences; in popular science writing these elements are often reintroduced to recreate an, albeit partially fictional, narrative. On the level of the history of science the same process of portraying a progressive narrative takes place. Thomas S. Kuhn, for example, has noted that text-books and popularisations reveal "a persistent tendency to make the history of science look linear and cumulative".[112]

In the case of popular science writing it is tempting to dismiss the tendency to create narratives of discovery as merely an attempt to make popular accounts more readable, but recall Leane's warning that "it is naive to dismiss the narrative structure of science popularizations as mere pedagogical scaffolding".[113] Narratives, like metaphors, play a far more significant role in the

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109 P.B. Medawar, 'Is the Scientific Paper a Fraud?', in P.B. Medawar, *The Threat and the Glory: Reflections on Science and Scientists* (New York: HarperCollins, 1990), pp. 228-33 (p. 233).

110 Greg Myers, 'Making a Discovery: Narratives of Split Genes' in *Narrative in Culture: The Uses of Storytelling in the Sciences, Philosophy and Literature*, ed. by Christopher Nash (London: Routledge, 1990), pp. 102-26 (pp. 102-3).

111 Myers, 'Making a Discovery', p. 107.

112 Kuhn, p. 139.

113 Leane, p. 131.

expository process than mere pedagogy – they perpetuate an image of scientific advance as "seamless and progressive".[114] Curtis criticises popular science writing's over-reliance on the detective story narrative, advocating more variation in form, and suggesting the Socratic dialogue as a viable alternative. Part of his criticism is precisely that "popular science, written in the narrative mode, is a powerful tool for promoting a particular normative view of science."[115] Imre Lakatos's *Proofs and Refutations*, a brilliant example of a dialogic exposition of a theory of scientific progress supports this assertion: written as the discussion between a teacher and his pupils – Pupil Alpha, Pupil Sigma etc. – this account is precisely anti-normative, identifying the normative force of 'formalism' which tends to "disconnect the history of mathematics from the philosophy of mathematics" and to "identify mathematics with its formal axiomatic abstraction".[116]

The reason for the normative force of narrative is, ironically, suggested concisely by Gould himself, though in inverted form. Early in *Life's Grandeur* he observes that "[w]e are story telling creatures, products of history ourselves. We are fascinated by trends, in part because they tell stories by the basic device of imparting directionality to time" (*LG*, 30), and later that "humans [...] are trend-seeking creatures (perhaps I should say "storytelling animals," for what we really love is a good tale – and [...] we view trends as stories of the best sort)" (*LG*, 78-9). But if trends are minimal stories, clearly the inverse also applies – stories imply trends. Concentrating for the most part on *Wonderful Life*, I will show how the narratives constructed imply the parallel, and in the end conflated, trends of scientific progress and teleological evolution.

Wonderful Life is self-professedly, self-consciously at times, a narrative of scientific discovery. In his Preface Gould describes how "[t]he reinterpretation of the Burgess Shale is a story, a grand and wonderful story [...] I have come to view this temporal sequence as an intense drama" (*WL*, 15). Already inherent in the chronological presentation of the reinterpretation is the idea of a scientific revolution, of overthrowing the status quo with a dramatic and brilliant new insight. Gould may describe it as "A Quiet Revolution" (*WL*, 79), but the clichés of painstaking and time-consuming hard work, leading to a moment of insight, are still evoked. Gould writes that "all the standard images of scientific discovery were violated by the revision of the Burgess Shale. All the romantic legends about field work, [...the] weeks of blood, sweat, toil and tears, the intrepid scientist [...] the most inaccessible point on the map" (*WL*, 80) – none of these, Gould claims, apply to the reinterpretation of the Burgess Shale. However, numerous examples of precisely these descriptions of meticulous study leading to intellectual breakthrough can be found

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114 Steve Fuller, *Science* (Buckingham: Open University Press, 1997), p. 19.
115 Curtis, p. 423.
116 Imre Lakatos, *Proofs and Refutations: The Logic of Mathematical Discovery*, ed. by John Worrall and Elie Zahar (Cambridge: Cambridge University Press, 1976), p .1.

throughout Gould's narrative. There may be no blood, sweat and tears but we learn that Whittington's expedition "split about seven hundred cubic meters of rock" (*WL*, 77), that Whittington "used the oldest method of all as his primary mode of illustration – patient and detailed drawing" (*WL*, 85), and that Whittington's "brilliant and eclectic student [...] made a systematic search through *all* the drawers" (*WL*, 80). Similarly Gould tells us how Whittington and his students dissected the fossils "by hand [...] grain by grain or flake by flake" (*WL*, 88), how they spent "countless hours" (*WL*, 92) mentally rotating the reconstructions, and how "Harry Whittington spent four and a half years just writing his first monograph on the genus *Marrella*" (*WL*, 107).

If Gould is aware of the "standard images of scientific discovery", he appears even more aware of the problems surrounding the depiction of moments of insight. In the standard image, following the weeks of field-work, the scientist "splits a rock [...] and cries Eureka! as he spies the fossil that will shake the world" (*WL*, 80). Later Gould is even more self-aware:

> I now come to the fulcrum of this book. I have half a mind to switch to upper case, or to some snazzy font [...] I am about to describe the key moment in this drama, but I am also committed to the historical principle that such moments do not exist. [...] Key moments are kid stuff. [...] I have laboured to master all the details and to arrange them in proper order. How can I now blow all this effort on the myth of eureka? (*WL*, 129-30)

Yet Gould cannot quite resist the construction of, as he puts it, "a Rubicon of sorts" (*WL*, 129). Gould describes this 'moment' in a pair of sentences: the first establishes an expectation, presents the information that the reader will require in order to appreciate whether or not there has been a 'discovery'; the second reveals the reality, the overthrowing of the expectation, and by implication the intellectual status quo:

> So Harry dissected, in full confidence that he would find the jointed appendages of an arthropod. Harry dissected – *and he found nothing under the carapace*. (*WL*, 131)

Gould may not use upper case, but instead he switches to italics; he also moves, in the space of the previous paragraph, from calling his protagonist Whittington, to Harry Whittington, to Harry. Moreover, the first sentence constructs Harry Whittington as "the perfect fool, with no preconceptions", not expecting to overturn conventional classification of the *Opabinia* fossil; the result is that his discovery is all the more objective, an essential element in Gould's narrative, because it contrasts with Walcott's 'shoehorn' – a result of preconceived ideas. Finally, it is to be presumed that the dissection of the *Opabinia* fossil, especially given the time-consuming nature of

the work described elsewhere, took days, probably weeks. In Gould's narrative of the 'moment of discovery', this length of time, the gradual realisation that must have dawned on Whittington, is compressed into an all-encompassing dash.

There is the suggestion in Gould's narrative of a fluctuation between his resistance to the idea of these key moments of discovery, and his construction of a narrative in which they figure as part of the advancement or progress of science. This is in evidence in his attitude towards Whittington's monograph on *Opabinia*: he first describes it as "one of the great documents in the history of human knowledge" (*WL*, 136) but almost immediately pulls back to a less sensationalist position – "*Opabinia*, just one case, is a shrug of the shoulders, not a discovery about life in general" (*WL*, 136). The same tension can be seen in a single sentence later in *Wonderful Life*: "But science is cumulative, for all its backings and forthings, ups and downs" (*WL*, 207). This same normative narrative of linear progressive science also surfaces in Dawkins's books. For example, he summarises the progress of the "remarkable theory [of the bacterial origin of mitochondria] championed by the redoubtable Lynn Margulis of the University of Massachusetts at Amherst, from heterodox origins, through grudging interest to triumphant near-universal acceptance today" (*RE*, 45). Here, the three-stage progression emphasises the linearity of scientific advancement.

One of the most striking pieces of evidence that there is a, as it were, 'covert' narrative of linear scientific advancement in *Wonderful Life*, is also one of the most surprising. Describing Simon Conway Morris's first five monographs on the Burgess Shale's "curiosities", Gould reverts to the very icon of linear progress that he has often criticised, and to which he has dedicated two complete chapters in his books, including one in *Wonderful Life* itself. Not once, but twice, Gould images Conway Morris as climbing "the ladder of evidence":

> Conway Morris mounted one rung higher on the ladder of evidence with his second treasure of 1976[;] (*WL*, 147)
>
> Simon's third mystery animal carried him another rung up the ladder of evidence. (*WL*, 149)

These remarkable sentences show that the narrative of the reinterpretation of the Burgess Shale is one of cumulative improvement, a narrative founded on a teleology of scientific progress.

This story is, however, not the only narrative in *Wonderful Life*. The history of this scientific study is told alongside a narrative of a contingent history of evolution which, Gould claims, is the necessary result of the Burgess reinterpretation. In a number of passages these two histories

meet, and, to an extent, combine. I will argue that in the partial conflation of these two narratives, and through other channels, the teleology of progress associated with scientific advancement seeps back into the apparently non-teleological depiction of evolution. At the very beginning of the book Gould describes the Burgess Shale as a "window upon that most crucial event in the history of animal life" but in the very next sentence notes that "[t]he story of the Burgess Shale is also fascinating in human terms" (*WL*, 24). Similar statements abound: "[This book is] first and foremost, a chronicle of the intense intellectual drama behind the outward serenity of this reinterpretation. Second, and by unavoidable implication, it is a statement about the nature of history and awesome improbability of human evolution" (*WL*, 24). In the Preface the two narratives are drawn into the same sentence, separated by a semi-colon: "*Opabinia* and company constituted the strange and wonderful life of a remote past; they have also imposed the great theme of contingency in history upon a science uncomfortable with such concepts" (*WL*, 14).

This conflation between the narrative of evolution and the narrative of scientific discovery is visible in a fairly unsurprising, but revealing, slippage. Scientific study and knowledge, in its exalted position, becomes not only a part of, but the culmination of, man's evolution. This is particularly true of scientific *self-knowledge*, of which the study of evolution, of our own origins, is the prime example. In these authors' books evolutionary *theory* becomes evolution's own end-point, imparting to the theory a teleology which it expressly denies. Dawkins opens his first book, *The Selfish Gene*, with a paragraph that immediately suggests the progress of evolution towards the watershed of scientific self-knowledge:

> Intelligent life on a planet comes of age when it first works out the reason for its own existence. If superior creatures from space ever visit earth, the first question they will ask, in order to assess the level of our civilization, is: 'Have they discovered evolution yet?' (*SG*, 1)

The implication is clear: the theory of evolution is the point towards which intelligent life progresses. The next sentence implies the corollary – intelligent life is also the point towards which evolution progresses:

> Living organisms had existed on earth, without ever knowing why, for over three thousand million years before the truth finally dawned on one of them. (*SG*, 1)

In exactly the same way, in *Life's Grandeur*, Gould, during a paragraph in which he denies that man is representative of mammalian success, still insists that "we are possessors of one extraordinary evolutionary invention called consciousness – the factor that permits us, rather than any other species, to ruminate about such matters" (*LG*, 15). This is not quite the grand

teleological narrative described by Thomas Lessl, or "a New Epic of Science" in Egers's phrase, in which "[c]osmic evolution, beginning with the big bang, begets chemical evolution, which begets biological evolution, which begets human evolution, which begets scientific evolution".[117] Nonetheless evolution is imagined as moving towards the end point not only of intelligent life, a standard anthropocentric attitude, but towards a form of life able to theorise their own origins.

An even more striking example comes from a passage from *Wonderful Life* that includes many of the features of popular science writing that I have sought to elucidate. Gould has been using an analogy of an intelligent-designer deity, "the Great Token-Stringer", putting together parts from a "grabbag" of basic anatomical features to form organisms of the diversity of those in the Burgess Shale. The end of this section runs:

> Perhaps his [the Great Token-Stringer's] natural vanity finally got the better of him. Perhaps he couldn't bear the thought of running such an exquisite play for so long, and having no chronicler to admire the work. So he let the token for more brain tumble from compartment 1 of the primate bag – and assembled a species that could paint the caves of Lascaux, frame the glass of Chartres, and finally decipher the story of the Burgess Shale. (*WL*, 218)

I would like to identify two implications contained in this passage. The first is that which I have observed above in Dawkins and elsewhere in Gould – the figuring of science, and especially evolutionary science, as the end-point of evolutionary progress. Here, this implication is strengthened by placing scientific study, of the Burgess Shale specifically, at the culmination of a three-part progression which runs from Palaeolithic cave art, through the religious art of Chartres, "and finally" to scientific study. The reference to Chartres recalls Henry Adams's observation that "All the steam in the world could not, like the Virgin, build Chartres", but inverting Adams's hierarchy in which science could never represent a force capable of creating Chartres cathedral.[118] Here Chartres is one point in a chronology that runs from Palaeolithic, through Medieval to Modern; but as Gould says of the cones of increasing diversity, we naturally conflate movement through time with progress in the sense of 'advancement'. The second implication comes close to embodying a form of the anthropic principle. In, albeit playfully, imagining the Great Token-Stringer, representing natural selection, as creating man *because* he wanted a species capable of understanding the process of natural selection itself, evolution is seen as a consequence of the need for intelligent life to arise, much as the anthropic principle sees the

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[117] Quoted in Leane, p. 138. On this grand narrative of evolution see also, Martin Egers, 'Hermeneutics and the New Epic of Science' in *The Literature of Science: Perspectives on Popular Science Writing* ed. by Murdo William McRae (Athens: University of Georgia Press, 1993), pp. 187-209.

[118] Henry Adams, *The Education of Henry Adams*, ed. by Ira B. Nadel (Oxford: Oxford University Press, 1999), p. 316. Ironically, Gould notes that "In the stained glass of Chartres, human history is portrayed as a linear sequence" when criticizing this sort of teleology of progress (*ESD*, 152).

'suitability' of the universe for carbon-based life as a consequence, not a cause, of the need for the development of intelligent life.[119]

Gould and Dawkins's popular science books reveal, then, a tendency to simultaneously represent science as a teleological progression and to evoke scientific self-knowledge, unsurprisingly evolutionary theory in particular, as a *telos* of evolution: science is projected as a linear and cumulative advancement towards knowledge, but this knowledge also represents the end-point towards which our own evolution progresses.

* * * *

As is clear from the earlier analysis of representations of genetics in popular science writing, that subject is intimately connected to the degree to which genes can be seen (or said) to 'cause' or 'determine' organismal traits. Often in popular science writing, as we have seen, this is an uninterrogated assumption; at most, writers may go as far as altering the respective 'doses' of encoded nature and contingent nurture, but rarely of rejecting the model entirely. In recent fiction which has taken an interest in genetics, on the other hand, the assumption of gene-centrism has often become the basis for ethical and epistemological concern – and as a result, interrogation. Thus, if one group of recent fiction writers seized upon the supposedly inherent *in*determinacy implied by twentieth-century physics (chapter 4) following the lead of popular science accounts of quantum mechanics (chapter 3), it is precisely the implication of genetic determinism, or a gene-centric account of development, that has interested other writers. Despite this contrast, it is once again around issues of causality and determinism that these engagements with science have often revolved. It is to these engagements that I will now turn.

[119] John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986).

6 Representing Biological Determinism in Contemporary British Fiction

6.1 Representing Genetics

As Patricia Waugh has noted in an excellent chapter on science and fiction in the 1990s, that decade saw a shift away from the physics and cosmology that in the 1980s had captivated the general public in popular science books and also exercised considerable influence over novelists.[1] If, she claims, the 1980s were the decade of physics then the 1990s saw interest swing towards the biological sciences and, with the press coverage of the impending culmination of the Human Genome Project, towards genetics in particular. It is no surprise, then, to find novelists embracing the topic in the 1990s, and perhaps even more so in the years since the announcement of the completion of the sequencing of the human genome in 2000.

In Chapter 4 I showed how by incorporating references to the new physics Ian McEwan's novels repeatedly engage with causality, determinism and inevitability. This connection is paralleled in McEwan's extensive use of the biological sciences in his novels. *Saturday* establishes many strata of determinism, but central is a presentation of the validity of both gene-centrism and reductive biological determinism: McEwan's central protagonist, Perowne, is convinced of the genetic cause of Baxter's condition. As far as he is concerned, Baxter's fate comes down to:

> Chromosome four [...] an excessive repeat of a single sequence – CAG. Here's biological determinism in its purest form. More than forty repeats of that one little codon, and you're doomed. Your future is fixed and easily foretold. (*Saturday*, hereafter *S,* 93)

McEwan's interrogation of biological determinism, and indeed his broader epistemological argument, begins by linking the inevitability of the onset of Baxter's disease to various other strata of determinism both within the novel's plot and outside it. On the simplest level this means that Perowne, we might say uncritically, attributes the very particular course of Baxter's (violent) actions after their initial car accident, to the onset of his Huntington's disease, and therefore to genetic, as opposed to environmental, factors. Although Perowne notes that "[violence] is not always a pathology; self-interested social organisms find it rational to be violent sometimes" (*S,*

[1] Waugh, p. 57.

88) (note the "not always [...] sometimes"), at the moment of Baxter's first punch Perowne diagnoses "reduced levels of GABA among the appropriate binding sites on striatal neurons" and muses that "there is much in human affairs that can be accounted for at the level of the complex molecule" (*S,* 91). This is strongly reminiscent of Pinker's description quoted above (Chapter 5.1, p. 92) of 'greedy reductionism' as the attempt to explain "education, conflict resolution, and other social concerns by studying the biophysics of neural membranes or the molecular structure of the synapse".[2]

Uncritical this reductionist gene-centrism may be, but it is in line with other views (Perowne's, we may presume) expressed elsewhere in the novel. Take, for example, this comment on parenting:

> It's a commonplace of parenting and modern genetics that parents have little or no influence on the characters of their children [...] what really determines the sort of person who's coming to live with you is which sperm finds which egg, how the cards in two packs are chosen, then how they are shuffled, halved and spliced[.] (*S*, 25)

This may be Perowne's view, but there is evidence even within the novel to the contrary: Perowne's confidence in this apparent commonplace is counterpointed by the important role that the children's maternal grandfather has played in their upbringing. John Grammaticus, the 'famous poet', instilled their artistic callings – music and poetry – in the children. Henry Perowne wonders whether he ever could have imagined that he would "one day father a blues musician" (*S*, 26), and although he "showed the nine year old Theo how it [the blues] worked" after that "grandfather took over" (*S*, 27). Likewise, it was Grammaticus who shaped the literary education of Daisy, having her learn poems and recite them to him. In the evening, when Theo and Daisy enter the room they "present a tableau of their respective obsessions and careers, precious gifts, Henry unjealously concedes, from their grandfather: Daisy holds a copy of her bound proof, her brother grips his guitar in its case by the neck" (*S*, 202). Grammaticus's influence is environmental, rather than genetic, and has profoundly shaped the children: blues and poetry are now central constituents of their lives and identities. As such, Grammaticus, the poet, contradicts the genetic determinism that Perowne, the scientist figure, espouses.

But Perowne's perspective remains a gene-centric one. Later in the novel, when Baxter returns to exact revenge for his earlier humiliation and holds Perowne's family at knife-point, Perowne asserts that it is "the unique disturbances, the individual expression of his condition – impulsiveness, poor-self-control, paranoia, mood swings, depression balanced by outbursts of

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2 Pinker, p. 70.

temper, some of this, or all of it and more" that have brought Baxter here, and are "driving Baxter on now" (*S,* 210). Baxter's violent actions may be unusual, but Perowne still sees them as 'expressions' (a word with strong genetic overtones) of his genetically caused condition.

Given my readings of popular science writing on genetics in the previous chapter it is particularly interesting to note how Perowne expresses his conviction in the genetic inevitability of Baxter's condition. In Chapter 5 I showed how popular science writing on genetics frequently utilises the metaphor of language, and of writing in particular, to emphasise a level of genetic determinism, or gene-centrism; certain forms of texts were shown to be particularly suited to this strategic metaphor. In *Saturday* McEwan, or perhaps Perowne, adopts precisely the same metaphor to describe Baxter's 'fate':

> Anyone with significantly more than forty CAG repeats in the middle of an obscure gene on chromosome four is obliged to share this fate in their own particular way. *It is written*. No amount of love, drugs, Bible classes or prison sentencing can cure Baxter or shift him from his course. It's spelled out in fragile proteins, but it could be carved in stone, or tempered steel. (*S,* 210)

The writing metaphor emphasises the permanence and fixity of the encoded information, enhanced here by the image of the carved stone or steel. Compare this with Matt Ridley's use of the same image, in the service of criticising the gene-centric approach: "genes are not immutable things handed down from our parents like Moses' stone tablets but are active participants in our lives".[3] This comparison also highlights not just the gene-centrism, but the connection to a fatalism with religious overtones that is picked up again at the very end of the novel: "This is his dim, fixed fate, to have one tiny slip, an error of repetition in the codes of his being, in his genotype, the modern variant of the soul" (*S*, 279). "*It is written*" – the italics draw attention to the phrase, underlining the conviction of the statement, but they also illustrate the metaphor – Baxter's fate is written *like this*, it is *as* written as this. Going further, the italics testify that Baxter's future is not just written in his genes, but it is also written *here*, in *this novel*. Self-consciously exposing the textuality of this narrative – of the written nature of Baxter's life – reveals an important aspect of our reading of McEwan's engagement with science and determinism: a certain metafictive awareness of the connection between determinism and narrative. I will return to this in a moment.

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[3] Matt Ridley 'What Makes You Who You Are: Which is stronger—nature or nurture?', *TIME Magazine*, 25 May 2003.

Perowne's biologically deterministic view is in evidence again towards the end of the novel. Seeing through his window the office workers and "the broken figures that haunt the benches" in the square outside his house,

> Perowne, the professional reductionist, can't help thinking it's down to invisible folds and kinks of character, written in code, at the level of molecules. (*S,* 272)

But in the moment of his greatest fears, Perowne has doubts about the genetic determinism that he maintains elsewhere in the novel:

> But for all the reductive arguments, Perowne can't convince himself that molecules and faulty genes alone are terrorising his family and have broken his father-in-law's nose. Perowne himself is also responsible. He humiliated Baxter in the street in front of his sidekicks[.](*S,* 210)

This hints at an alternative causality, one based not on genetic, biological or pathological determinism, but on a responsibility for our conscious decisions. The words 'responsible' and 'terrorizing' would seem to link this alternative argument to the novel's political dimension: the anti-war marchers, we might suggest, are aware that the consequences of actions must be weighed. At the very end of the novel Perowne again acknowledges his responsibility: "He's responsible, after all; twenty hours ago he drove across a road officially closed to traffic, and set in train a sequence of events." Perowne decides to drop the charges against Baxter and ensure that he is provided with good care as his condition deteriorates. Contrary to the biologically deterministic perspective, Perowne knows that "the difference between good and bad care is near-infinite" and that this "is one area where Henry can exercise authority *and shape events*" (278, my italics). Baxter's fate is not entirely 'in his genes', and Perowne can, to a limited extent, affect it.

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If the Human Genome Project was one catalyst for novelists' interest in genetics in the 1990s and 2000s, the successful cloning by Ian Wilmut and his colleagues of Dolly the Sheep, the first mammal to be cloned from an adult somatic cell, was surely another. Although she makes no explicit reference to Dolly, the news of Dolly's birth in July 1996 must surely have been an influence for Margaret Atwood who had, by the time she started writing *Oryx and Crake* (2003) in March 2001, already "been clipping small items from the back pages of newspapers for years, and noting with alarm that trends derided ten years ago as paranoid fantasies had become

possibilities, then actualities".[4] Cloning, and genetic modification – 'crosses' of, say, pigs and baboons – are a central part of the dystopian society in *Oryx and Crake*, but also the key to Crake's 'children', a breed of 'improved' humans who will re-populate the earth – a genetically engineered genesis.[5]

Clones, or 'fabricants', are also the focus of Somni~451's story, one of the six interlocking narratives in David Mitchell's *Cloud Atlas* (2004), and of Kathy H.'s account of her life in Kazuo Ishiguro's *Never Let Me Go* (2005).[6] In both novels, clones represent an underclass controlled by and for the benefit of non-cloned society: in *Cloud Atlas*, Somni~451 and the other clones take on the menial jobs in a distant future society; in Ishiguro's sinister vision of a 1990s Britain "somewhat adjacent to the one we know", set "not in a Britain-yet-to-come, but in a Britain-off-to-the-side" as Margaret Atwood puts it, clones are kept as organ 'donors' for society.[7]

In both *Cloud Atlas* and *Never Let Me Go*, the links between human cloning and determinism are strong. Both novels enact (and, interestingly, ventriloquize) the coming to consciousness of clones – the realisation of the pre-determined state of their lives; in both novels too the clones – Somni~451 in *Cloud Atlas* and Kathy H. and Tommy in *Never Let Me Go* – attempt to break free from their fates, and in both cases their attempts are essentially futile. Somni's story takes the form of an interview with an archivist conducted, we quickly learn, before Somni's "xecution in the Lighthouse" (*CA*, 189), and tells how she was rescued from the determined world of her serving job by anti-cloning terrorists. We follow her as she 'ascends' from her drug induced intellectual apathy, leaves her dinery prison and joins the terrorist organisation Union to act as a fabricant ambassador: we see the transformation in her life as a shift from the completely determined monotony of her serving life to what appears to be greater freedom and free will. As her story draws to a close, however, we learn that the transformation is an illusion, a fact which has been subtly signalled at the very moment of the hinge in her narrative, when Somni is given a (Hobson's) choice by the Unionman Mr Chang:

> I could leave the dinery that morning, go Outside and repay my Investment in a new way; or I could remain in Papa Song's [...] and wait for my ascension to

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4 Margaret Atwood, 'Perfect Storm: Writing Oryx and Crake'.

5 Margaret Atwood, *Oryx and Crake* (New York: Anchor Books, 2004).

6 David Mitchell, *Cloud Atlas* (London: Hodder and Stoughton, 2004); Kazuo Ishiguro, *Never Let Me Go* (London: Faber and Faber, 2005). All subsequent references are to these editions, hereafter *CA* and *NLMG*, and will be made in the text.

7 James Wood, 'The Human Difference', review of Kazuo Ishiguro, *Never Let Me Go* in *The New Republic Online*, 12 May 2005 <http://www.powells.com/review/2005_05_12.html> [accessed 10 April 2010]; Margaret Atwood, 'Brave New World', review of Kazuo Ishiguro, *Never Let Me Go* in *Slate*, 1 April 2005 <http://www.slate.com/id/2116040> [accessed 10 April 2010].

be brought to lite and to suffer its consequences.

Not much of a choice.
It was the first choice of my life, and simpler than most since.
(*CA*, 208)

At the culmination of her story, Somni describes her capture by Unanimity, the state police, and we learn that even the apparently free life she has led since leaving the dinery was in fact scripted, pre-determined for the purpose of propaganda:

You are implying that you xpected the raid, Somni?
Once I had finished my manifesto, the next stage could only be my arrest.

What do you mean? What 'next stage' of what?
Of the theatrical production, set up while I was still a server in Papa Song's.

[....]

Do you regret the course of your life?
How can I? 'Regret' implies a freely chosen, but erroneous, action; free will plays no part in my story.
(*CA*, 363, 365)

The dynamics of free will and determinism in *Cloud Atlas* are mostly played out against a backdrop of Nietzschian 'will to power' rather than of deterministic science. Thus Somni's fated life, pre-determined for her, is as much a consequence of her enslavement and the scripting of her life by the dominant powers in her society, as it is of her genetic makeup. But the 'genoming' of the fabricants, the genetic alterations made to them, is a crucial part of society's control over them. As Somni herself points out "[a]s a fabricant xpires after forty-eight hours without a highly genomed Soap [fabricant food] whose manufacture and supply is the Corp's monopoly, 'it' will not run away" (*CA*, 341). Of course, genoming is simply a technologically advanced form of control – a similar system is devised, in an echo of the kind typical of *Cloud Atlas*, by the nineteenth-century missionaries of Bethlehem on Raiatea, who have "instill[ed] in the slothful so-an'-sos [Polynesians] a gentle craving for this harmless leaf [tobacco]" to "give him an incentive to earn money, so he can buy his baccy [...] from the Mission trading-post" (*CA*, 501).

Never Let Me Go tells the story of a group of childhood friends. The details of the gossip and relationships at their school are wonderfully banal, but are set against a backdrop of bleak inevitability: as the narrative progresses it becomes clear that the fates of these friends are predetermined – as clones they live to provide organs for non-cloned members of society. Towards the end of the novel the narrator Kathy H and her lover Tommy come to believe rumours that their 'donations' can be delayed because they are in love. The rumour is unfounded

– the course of their life cannot be diverted. As James Wood sees in his review of *Never Let Me Go*, the completely predetermined nature of the cloned children's lives is really an allegory for the futility of our own:

> Their [the cloned children's] lives have been written in advance, they are prevented and followed, in the words of *The Book of Common Prayer*. Their freedom is a tiny hemmed thing, their lives a vast stitch-up.
>
> We begin the novel horrified by their difference from us and end it thoughtful about their similarity to us. After all, heredity writes a great deal of our destiny for us [...].[8]

If the clones are genetically (and to a degree socially) determined, then it is only an extension of the ways in which we are ourselves. Clones seem to represent genetically determined beings *par excellence* (though they are not, perhaps, any more so than twins), but if genetic determinism holds, it holds for us as well.

The connection between narrative and determinism that is evident in these novels can also be seen in *Saturday*, in Perowne's realisation of the inevitability of Baxter's arrival at the Perowne house in the novel's second major confrontation:

> It is, of course, logical that Baxter is here. For a few seconds, Perowne's only thought is stupidly that: *of course*. It makes sense. Nearly all the elements of his day are assembled; it only needs his mother, and Jay Strauss to appear with his squash racket. (*S,* 206)

Within the diegesis, Perowne's feeling – 'Of course!' – is one we might recognise. But looking from a perspective outside the narrative (this metafictive perspective is again signalled by the typographical change to italics) it is indeed logical that Baxter has returned to centre stage; and the feeling of the designed assembly of Perowne's day is also unsurprising – McEwan is, after all, bringing together the narrative elements required for his dramatic denouement. Given the drama of the climactic scene, Henry's game of squash with his colleague Jay Strauss and his visit to his mother, might initially seem like interruptions to the novel's narrative. But, with Perowne's realisation that their appearance would complete the assemblage, McEwan draws them back into the narrative, asserting the role that they play.

Perowne's game of squash with Jay Strauss complements and extends his violent exchange with Baxter that immediately precedes it. In many ways, it is the narrative's proxy for Baxter's reaction to his humiliation. Consistently following, as it does, Henry Perowne's passage through his day,

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8 James Wood, 'The Human Difference'.

the narrative cannot examine Baxter's own thoughts: as a result, the chain of events that links Perowne's earlier encounter with Baxter with the finale is kept from the reader. The aftermath of that altercation is instead represented in the surrogate of the squash game. The frustration of defeat, and the anger that stems from such a defeat, is made apparent by, and to, Perowne; the game enacts the similar and simultaneous 'off-stage' emotions of Baxter. As such, the inevitability of Baxter's return is not signalled in the narrative (we do not see Baxter deciding that he will go to Perowne's house) – but that inevitability is later apparent to Perowne, and is signalled in the formal system of the novel.

This strict form acknowledges the determinism of narrative itself. By having Perowne realise the relevance, or at least the connectedness, of the day's events McEwan draws back the veil to reveal that this highly formal circadian novel has a narrative inevitability or determinism, even predictability – and he does so at the point at which he most needs to maintain the plausibility of the narrative. This same flaunting of implausibility occurs during the finale, at the precise moment that Baxter may or may not have been affected by Daisy's reading:

> his grip on the knife looks slacker, and his posture, the peculiar yielding angle of his spine, suggests a possible ebbing of intent. Could it happen, is it within the bounds of the real, that a mere poem of Daisy's could precipitate a mood swing? (*S,* 221)

Given the fragility of this moment's plausibility, the phrase "within the bounds of the real" daringly risks collapsing the delicate realism. On one level, that of the diegesis, this is Perowne's question; on another it is McEwan's – *Saturday* "poses the question: what does literature do?", or as Deryn Rees-Jones frames it, "What are poems for?".[9] At other moments in the novel we can hear a similar intrusion of McEwan's voice through Perowne's thoughts – often when Perowne contemplates literature:

> Unlike in Daisy's novels [recommendations to Perowne from his daughter], moments of precise reckoning are rare in real life; questions of misinterpretation are not often resolved. Nor do they remain pressingly unresolved. They simply fade. (*S,* 156)

Unlike the previous example, this is rather more difficult to interpret. The simplest reading might attribute this to what we could call Perowne's 'literary scepticism': literature, as I will show in a

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[9] David Amigoni, '"The Luxury of Storytelling": Science, Literature and Cultural Contest in Ian McEwan's Narrative Practice' in *Science and Literature*, ed. by Sharon Rushton (English Association: Boydell and Brewer, 2008), pp. 151-67 (p. 161); Deryn Rees-Jones, 'Fact and Artefact: Poetry, Science, and a Few Thoughts on Ian McEwan's *Saturday*', *Interdisciplinary Science Reviews*, 30 (2005), 331-40 (p. 331).

moment, has little epistemological value in Perowne's view. But there is a metafictive irony at Perowne's expense – he does not believe in 'moments of precise reckoning', and yet *Saturday* presents us with several examples: the moment the policeman waves him across Tottenham Court Road, his diagnosis of Baxter's condition, or Daisy's reading of 'Dover Beach'. This illustrates the way in which *Saturday* carefully positions its critique of competing epistemological systems. Perowne, the scientific realist, the rationalist, is rightly critical of the reductionism of even realist novels; and yet this novel draws us into an examination of the power of those moments of reckoning, by placing them at the heart of its narrative. By gently reminding us, at crucial moments, of the fictionality of his novel, McEwan appears to ask us to consider whether or not these representations correspond to real life – whether, in other words, art can contain truth. As we shall see, the novel seems to resist any easy answer to this question.

In the two moments of potentially violent conflict in which Perowne finds himself on this day, McEwan presents us, evidently, with two resolutions achieved in different ways. In the first, Henry Perowne uses his diagnosis of Baxter's condition – built up from observations made out of professional habit – and his knowledge of its genetic basis, to undermine Baxter's authority and to escape the situation relatively unharmed. His diagnosis is, in emulation of the scientific method, based on the accumulation of evidence:

> The persistent tremor [of Baxter's hand] also draws Perowne's professional attention. (*S,* 87)
>
> Perowne's attention, his professional regard, settles once again on Baxter's right hand. It isn't simply a tremor, it's a fidgety restlessness implicating practically every muscle. (*S,* 90)
>
> Watching him unobserved for a few seconds, Perowne suddenly understands – Baxter is unable to initiate or make saccades – those flickering changes of eye position from one fixation to another. (*S,* 91)
>
> Even as he turns back [...] there remains in a portion of his thoughts a droning, pedestrian diagnostician who notes poor self-control, emotional lability, explosive temper, suggestive of reduced levels of GABA among the appropriate binding sites on striatal neurons. (*S,* 93)

The emphasis here is on observation – 'attention', 'watching', 'regard' – and this culminates in a full diagnosis:

> small alterations of character, tremors in the hands and face, emotional disturbance, including [...] sudden, uncontrollable alterations of mood, [...] helpless jerky dance-like movements, intellectual dilapidation, memory failure, agnosia, apraxia, dementia, [...] nightmarish hallucinations and a meaningless

end. (*S,* 94)

In the initial observations the gradual accumulation of evidence is accompanied and emphasised by the progression from non-technical ("tremors") to highly technical ("saccades", "striatal neurons") vocabulary. This same progression is also evident in the diagnosis – with the exception of the final subjective prognosis, which instead glances forwards to Perowne's visit later in the day to his mother. On the face of it, then, the means by which Perowne is able to escape more serious injury is a model of inductive scientific reasoning.

In the later conflict in Perowne's home, in which Baxter holds a knife to Rosalind's throat and threatens to rape Daisy, Perowne appears powerless – indeed, his rational approach repeatedly dismisses ideas of heroism as unrealistic. Instead, it is Daisy's reading (technically, recital) of 'Dover Beach' which changes the momentum of the situation. Baxter is apparently overwhelmed by the poetry, and his mood changes to one of manic euphoria, and the worst of the danger is passed. To put it crudely, the earlier solution is scientific, the later artistic.

"On the face of it," David Amigoni observes, "McEwan seems to participate in and extend C.P. Snow's 'two cultures' perspective on science, the humanities and the cultural contest in which they are involved".[10] In *Saturday*, just as with Joe and Clarissa in *Enduring Love* (which I will examine later), the opposition is manifested in the positions and disagreements of Perowne and Daisy, with the two cultures divided along the same gender lines in both novels. Perowne's inability to appreciate literature, what I earlier called his literary scepticism, runs in parallel with, and is connected to, his respect for science: "He doesn't seem to have the dedication to read many books all the way through" and he mocks the "so-called magical realists" who do not even present a "recognisable physical reality" citing a number of examples – including, amusingly, the scene from McEwan's own *The Child in Time* in which the protagonist sees "through a pub window his parents as they had been some weeks after his conception, discussing the possibility of aborting him" (*S*, 66, 67). Perowne is, in Daisy's view, "a coarse, unredeemable materialist" (*S*, 134) and he himself asks what, really, he learned from *Anna Karenina* and *Madame Bovary* other than that "adultery is understandable but wrong, that nineteenth-century women had a hard time of it" and so on: Perowne does not want "the world reinvented; he wants it explained" and science, in his view, does this in a way that literature cannot (*S*, 67, 66). His, then, is an exclusively scientific epistemology, which does not admit of the possibility of literature as a form of knowledge, or even really of literature being in any way 'useful'. Even though poetry proves to be exactly that in the novel's denouement – as John Grammaticus says, "[w]ho would have thought

[10] Amigoni, p. 154.

that learning poems by heart for pocket money would turn out to be so useful" (*S*, 232) – it is not at all clear that Perowne's conviction will change.

In this regard Perowne is similar to those other scientific, male protagonists of McEwan's recent novels. In *Enduring Love*, Joe Rose laments the "derisory" science collection of the London Library where "[t]he assumption appeared to be that the world could be sufficiently understood through fiction, histories and autobiographies", and asks whether the "scientific illiterates who ran this place, and who dared call themselves educated people, really believe[d] that literature was the greatest intellectual achievement of our civilization?" (*EL*, 42). Michael Beard, in *Solar*, gives himself a crash-course in Milton and in the process comes to "suspect a monstrous bluff. The reading was a slog, but he encountered nothing that could remotely be construed as an intellectual challenge, nothing on the scale of difficulty he encountered daily in his [physics] course".[11]

However, even if his principal characters appear to be unproblematically scientific (or, with his female characters, literary) the temptation to locate McEwan's writing as lying comfortably within a 'two cultures' model should be resisted. In an article on "poetry, science and a few thoughts on Ian McEwan's *Saturday*", Deryn Rees-Jones attempts to "think through the kind of knowledge a poem constitutes" – a complex question a version of which I will ask in the conclusion to this thesis. She asks: "Is McEwan then on the side of poetry, even as he celebrates, through Henry, the rationalism of science?" (335). McEwan does not, I think, takes 'sides' in *Saturday*; even if a clear opposition between literature and science is created, the novel's position is critical of precisely this division. I read *Saturday* as trying, in a similar way to Rees-Jones's own article, to think through the kinds of knowledge that scientific and literary discourses might constitute, and in what ways scientific knowledge in particular is contested and contestable; in this I agree with Amigoni's assessment that "McEwan's fiction interrogates what science may mean in the lives of western subjects [...] It acknowledges a broader cultural narrative of which scientific discourses are an insistent, authoritative and in some sense contested component. McEwan's fiction contributes subtly, intelligently and imaginatively to that process of contestation".[12]

Science (particularly genetics and medical science) and art (represented by literature and, especially, poetry) *are* placed in opposition in this novel, especially in the two central 'crises' of the narrative; but an appreciation of this apparent 'two cultures' model must also realise that the details of the resolutions to both crises add considerable complexity to the simple binary

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11 McEwan, *Solar*, p. 201.
12 Ibid.

(science/arts) reading just offered. On the simplest level, the earlier, scientific approach does not in fact defuse the situation, but exacerbates it. Rees-Jones is right to observe that "it is the fallibility of the human scientist which provokes the invasion into the private world of the family", but is not so clear cut as her claim that in "a melodramatic showdown towards the end of the novel, it is, however, poetry which saves the day" and later that "symbolically it is poetry and music which repel the dangerous invader".[13] I would argue that the later artistic intervention is not a deliberate attempt to resolve the danger of the situation (Daisy is not, it seems fair to say, attempting to wrest control of the situation as Perowne self-consciously does after the car accident), nor does it in itself remove the immediate danger, though it does alter Baxter's mood. Perowne is aware that the danger has not passed: Baxter's state of mind remains "delicately poised, easily disturbed. It's important not to surprise or threaten him", but "Rosalind and Daisy remain in their embrace – hard to believe they think they're out of danger" (*S*, 222, 224)) In the end the situation is resolved by Perowne's deceit and some fake science, as Perowne tells Baxter he has details of a possible cure upstairs, and ultimately by violence, as Theo and Henry together throw Baxter down the stairs. Indeed, even the poetry reading itself is a deception. Baxter is impressed less by the poem, than by the fact that Daisy wrote it – "You *wrote* that" he keeps repeating (*S*, 222); but the poem, of course, is Arnold's.

Similarly, the earlier scientific resolution has also qualities of the non-scientific. Perowne's diagnosis may be classically inductive, but at the point at which he acts on his conclusions Perowne "has the impression of a witchdoctor delivering a curse" (*S*, 94) and is aware that "[t]hey are together, he [Baxter] and Perowne, in a world not of the medical, but of the magical. When you're diseased it is unwise to abuse the shaman" (*S*, 95). These comments reveal the fact that although the basis for Perowne's dominance in the ensuing exchange with Baxter may be the knowledge that he has arrived at through his scientific observation and training, the model for this power dynamic is anything but unique to scientists.

An alternative reading could, instead of seeing *Saturday* as a paean to the rationality of science, attribute the successful resolution of both situations to the ability of both Perowne and Daisy to fictionalize, to create a convincing narrative. The line between fiction and deception is indistinct: Perowne, thinking of a poem of Daisy's – 'The Ballad of the Brain on my Shoe' – that "resulted from Daisy's visit to the operating theatre one morning to watch her father at work", wonders at "art's essential but – he had to suppose – forgivable dishonesty" (*S*, 139). Daisy entrances Baxter, she "recited a poem that cast a spell on one man [...] he was transfixed by it [...] Baxter heard what Henry never has [...and it] touched off in Baxter a yearning he could barely begin to define"

[13] Rees-Jones, p. 337, p. 334, p. 337.

(*S*, 278-9). But even before she does so, Perowne has told Baxter a story, one that he desperately wants to hear, of "a new drug, not on the market, but just arriving here for trials [...] I can get you on the trial" (*S*, 215). Perowne knows that Baxter "wants to be convinced" (*S*, 216) – he identified the same desire, "a hunger for information, or hope", in their earlier confrontation: "Perowne is familiar with this impulse in patients, this pursuit of the slenderest of leads [...] it's necessary for Baxter to check. And check again. Someone might know something he doesn't" (*S,* 96-7). After the car accident, Perowne begins to reconstruct Baxter's narrative, starting with the rather dramatic line "Your father had it. Now you've got it too." Perowne continues to draw out Baxter's story – his parents, where he grew up, where he lives – until "he's accepted Perowne's right to interrogate. They've slipped into their roles" (*S*, 94-6). Narrative, Perowne sees, has its own momentum – "nothing can be predicted, but everything, as soon as it happens, will seem to fit" (*S*, 87).

6.2 Representing Evolution

Saturday presents, and critiques, Perowne's belief that the events that take place on that eventful February day are a result, albeit an indirect one, of Baxter's genetically determined condition. Like *Saturday*, *Enduring Love* is also concerned with the factors that affect our lives, and likewise sees our fates as partly shaped by a form of biological determinism. But whilst in *Saturday* this biological determinism is written in Baxter's genes, in *Enduring Love* it is the result of our instincts instilled over the course of our evolutionary development.

The same reductive determinism that I identified in Perowne's tendency to look for explanations for the dreadful situation in which he and his family find themselves "at the level of the complex molecule" (*S*, 91) can also be found in Joe's interpretation of the world. Describing the balloon, for example, Joe thinks of the helium inside:

> that elemental gas forged from hydrogen in the nuclear furnace of the stars, first step along the way in the generation of multiplicity and variety of matter in the universe, including our selves and all out thoughts. (*EL,* 3)

This excellent pastiche of popular science writing further underlines the arbitrary notional beginning to this narrative (see Chapter 4). But the absurdity of trying to explain the balloon, and the balloon accident, via a history of the universe also illustrates the problems of 'hard' or 'greedy' reductionism. Furthermore, this particular lineage – from elemental gas, to matter, to

humans, to conscious thought – should also remind us of the anthropocentric teleology identified in popular science writing on evolution in Chapter 5.

A similar reductionism, and a form of biological determinism, is in evidence in Joe's attempt to explain the men's decisions to let go of the ropes through the biological and social evolution of selfishness and altruism. Like Henry Perowne in *Saturday* and the popular science writers examined in Chapter 5, Joe Rose (also, of course, a popular science writer) turns to the metaphor of writing to express the unalterable and inevitable, in this instance the conflict of co-operation and selfishness established in our natures by evolution:

> [...] there was a deeper covenant, ancient and automatic, written in our nature. Co-operation – the basis of our earliest hunting successes, the force behind our evolving capacity for language, the glue of our social cohesion. [...] But letting go was in our nature too. Selfishness is also written on our hearts. (*EL*, 14)

Their behaviour, in Joe's view, is governed by instincts formed by our evolutionary development. Initially Joe describes his decision to hang on to the rope in rational terms: "The child was incapable, and was about to be borne away. Two miles to the west were high-voltage power lines. A child alone and needing help. It was my duty to hang on". But when it comes to it he realises that "The child was not my child, and I was not going to die for it". The reference here, of course, is to the relevance of kinship in governing 'altruistic' behaviour – an important factor in the socio-evolutionary study of inter-personal behaviour. In an interview with Ramona Koval McEwan remarked, in a brief exchange about E. O. Wilson, that "there's plenty of evidence that suggests people will go a lot further to defend their child than someone far away whom they can't see".[14]

Later, having decided that the threat that Jed Parry poses is serious, Joe buys a gun from some ageing, disillusioned hippies, and afterwards stops in some woodland to try firing it. Finding that his "bowels had gone watery" (*EL*, 106) Joe walks off into the woods, and as he squats he scoops up a handful of soil:

> I brought my palm close to my face and peered. In the rich black crumbly mulch I saw two black ants, a springtail, and a dark red worm-like creature with a score of pale brow legs. These were the rumbling giants of this lower world, for not far below the threshold of visibility was the seething world of the roundworms – [...] even these were giants relative to the inhabitants of the microscopic realm[.] (*EL*, 207)

[14] Ramona Koval, 'Ian McEwan', Books and Writing (Radio National), 22 September 2002 <http://www.abc.net.au/rn/arts/bwriting/stories/s679422.htm> [accessed 8 March 2010].

Seeing and imagining these creatures, fungi and bacteria in the soil Joe notes the "blind compulsion of these organisms to consume and excrete" which makes "possible the richness of the soil" (Ibid). Joe looks for consolation in the fact that we are "still part of this natural dependency", but instead concludes that we are "no longer in the great chain" (Ibid). What brings Joe to this apparent realisation is the thought of his vehicle, his gun, the roads, the city, his apartment – objects of modern civilization that are outside the 'natural' order. Amigoni argues that in McEwan's fiction humans are necessarily in both the natural and social orders at the same time, finding evidence for this in *Enduring Love* in passages such as that in which Joe Rose, engaging "simultaneously [...] in two of life's central, antithetical pleasures, reading and fucking", manages to be "in two places at once" (*EL*, 161, 158). Humans sit in two worlds: on the one hand, we are in a determined narrative, still bound by the "blind compulsion" of instinct that governs the organisms in the soil – it is, after all, precisely the same "compulsion [...] to [...] excrete" which drives Joe into the woods "to enrich the forest floor"; but on the other, we are also in a "mess of our own unmaking" (*EL*, 207), in a non-determined narrative governed by our conscious decisions, by our post-natural rationality. Or, as Amigoni puts it, we are "in a world conditioned by both biological determinism and indeterminate proliferating social and cultural meanings".[15]

This adheres well to the narrative model of *Enduring Love*. I have shown how Joe's narrative is affected by contingency in the shape of the balloon in chapter 4 (see above, p. 79 ff.); but it is also affected by his instincts shaped over evolutionary time and by his own rational decisions. As I have already discussed, when Joe lets go of the rope, instinct wins out over rationality: not a rational decision, but an instinctive reaction that is itself the consequence of evolution. Even John Logan's momentary hesitation Joe attributes to the "flame of altruism" which "burned a little stronger" in him (*EL*, 15), as opposed to a conscious decision. Whether or not this is true is impossible to ascertain, since our perspective is focussed through Joe's opinions. Logan may have acted in the assumption that, contrary to Joe's belief that even if there was "a vague communality of purpose, we were never a team" (*EL*, 10), they would all continue to work together. The basis for such an assumption would be a rational assessment, as opposed to an instinctual reaction based on our evolutionarily conditioned tendency for self-preservation, and preservation of our kin. But it is in keeping with Joe's perspective that he attributes Logan's hesitation to the "flame of altruism", part of the "covenant, ancient and automatic, written in our nature" (*EL*, 15, 14).

On the other hand, when Joe does his research into de Clérambault's Syndrome, say, or decides to meet the threat of Jed Parry with violence, and sits down to find in his address book a friend

15 Amigoni, p. 153.

able to procure him a gun, he acts rationally – beyond the instincts displayed by the insects. This opposition between instinct and rationality can also be seen played out in an incident soon after the balloon accident. Reading for an article on the decline of narrative in science, Joe reads an anecdote about a dog which appears to exhibit rational decision making and an awareness of the consequences of its actions. Distracted, Joe stops his note-taking: "the last words I had written before losing control of my thoughts had been '*intention, intentionality, tries to assert control over the future*'. These words referred to a dog when I wrote them, but re-reading them now I began to fret." (*EL*, 43) The point about the story of the dog is: does it act rationally, or does it act according to basic non-conscious instincts? This is the reason that it is so apposite that the words '*intention, intentionality, tries to assert control over the future*' (*EL*, 43) can apply to both the dog and to Joe – because this asks the same question of Joe as he is asking of the account of the dog: do we attribute behaviour to rationality, to conscious choice, or to instinct? Perhaps Joe feels uncomfortable – the "pricking along my nape and a rawness in my gut which resolved itself, for the third time that day, into an unreliable urge to crap" (*EL*, 40) – not because of the perceived threat of a stranger, but rather because the story asks questions of his actions that he is not asking of himself – whether his letting go of the rope was instinctive, and so to a degree biologically determined, or a rational, and thus selfish, decision.

Joe Rose's examination of the forest soil bears a striking resemblance to a description from A.S. Byatt's 'Morpho Eugenia', the first of the two stories that together form *Angels and Insects*.[16] William Adamson, the protagonist, is searching for ants:

> Under his gaze the whole wood-floor became alive with movement, a centipede, various beetles, a sanguine shiny red worm, [...] He took out his magnifying lens and looked at a patch of moss, pebbles and sand, and saw a turmoil of previously invisible energies, striving, striving, white myriad-legged runners, invisible semi-transparent arthropods, button-tight spiderlings. His senses, and his mind attached to them, were like a magnetic field, pulled here and there. (*A&I*, 37-38)

Insects, and their "blind compulsion", are the basis for the extended analogy used in this novella, which likewise addresses the twin worlds of instinct and rationality. In Byatt's own words, the

> idea for the story was fairly simple. A young scientist marries the daughter of an old clergyman-collector and becomes trapped in a country house which turns out to resemble an antheap, in that it is uncertain whether the source of

[16] A.S. Byatt, *Angels and Insects* (London: Chatto & Windus, 1992). All subsequent references are to this edition, hereafter *A&I*, and will be made in the text. Byatt quotes the passage from *Enduring Love* in 'Ancestors' in *On Histories and Stories*, pp. 65-90 (p. 83).

> authority is the incessantly childbearing females or the brisk sexless workers.[17]

The story is simple enough, but the analogical structure is complicated. It is true that Bredely Hall does come to resemble an antheap: as William studies the ant colonies in the grounds, and as he begins to understand the dynamics of the household, the reader sees the similarities between the two. The allegory is carefully constructed and maintained, with regular references to the correspondence. Lady Alabaster, the fecund queen, is pampered and waited upon, and the long description of her closely resembles those of the ant Queens:

> The room was a nest of cushions [...] She seemed to spend most of her day drinking – tea lemonade, ratafia, chocolate mild, barley water, herbal infusions, which were endless moving along the corridors [...] She also consumed large quantities of sweet biscuits [...] which were also freshly made by Cook, carried from the kitchen, and their crumbs subsequently removed, and dusted away. She was hugely fat [...] William felt that this immobile, vacantly amiable presence was a source of power in the household. (*A&I*, 27)

William frequently muses on "his own drone-nature, as he increasingly perceived it" (*A&I*, 105):

> he was hard put to it not to see his own life in terms of a diminishing analogy with the tiny creatures. [...] His vision of his own biological processes – his frenzied, delicious mating, so abruptly terminated, his consumption of the regular meals prepared by the darkly quiet forces [...] brought him insensibly to see himself as a kind of complex sum of his nerve-cells and instinctive desires[.] (*A&I*, 100)

In many ways the ants, as Jon Turney observes of the clones in *Never Let Me Go*, "underpin an allegorical story": "To ask," William Adamson realises in a piece of writing for the popular science book he writes with Matty Crompton, "what are the ants in their busy world, is to ask, what are we" (*A&I*, 116).[18]

But the comparison between the insect societies and human society is complicated by Byatt's reminders of the dangers of analogy. In a discussion that moves from slavery in ants to the "unfortunate slaves" "across the Atlantic", Matty shows an awareness of the problem – "I do not know quite where these thoughts may lead us" – and William concludes even more explicitly that "'Analogy is a slippery tool [...] Men are not ants'" (*A&I*, 100). Later, he repeats the conclusion to himself: "Men are not ants, said William Adamson to himself, and besides, the

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17 A.S. Byatt, 'True Stories and the Facts in Fiction' in *On Histories and Stories*, pp. 91-122 (p. 116).

18 Jon Turney, 'Science communication in fiction' in *Practising Science Communication in the Information Age*, ed. by Richard Holliman, Jeff Thomas, Sam Smidt, Eileen Scanlon, and Elizabeth Whitelegg (Oxford: Oxford University Press, 2008), pp. 166-77 (p. 173).

analogy will not do" (*A&I*, 106). And if Byatt warns us about comparing men to ants, she also, in this story and elsewhere, expresses her concerns about comparing insect societies to human ones:

> I began with an instinctive aversion to anthropomorphic personifications – Maeterlinck's Queen Ant in her bridal veiling, committing infanticide, or whimsical parallels between insect armies, rulers and 'servants' with human hierarchies. I worry about anthropomorphism as a form of self-deception.[19]

Having read an account that William writes of the merciless behaviour of the hive or nest towards the male bees and ants, Matty rather knowingly responds:

> 'Very eloquent [...] I am quite overcome with pity for these poor, useless male creatures. I must admit I had never seen them in that light before. Do you not think you may have been somewhat *anthropomorphic* in your choice of rhetoric?' (*A&I*, 104)

Here, the situation is more complex; Matty, William will later realise, often speaks in riddles, and here she is not being entirely candid. Ostensibly, Matty is responding to anthropomorphic comparisons in the story that describe the ants as human – "the males, too, have become specialised, as factory-hands are specialised *hands* for the making of pin-heads or brackets" (*A&I*, 103), for example – but she also perceptively sees that William is increasingly identifying himself as a drone. Analogies, as I discuss below, are often invertible. Her veiled criticism, then, is rather of the implicit zoomorphism. Seen this way, and within the wider context of the story, we can translate her comment thus: 'Do you not think that you may have taken the analogy too far? You are not actually an ant, trapped within an incestuous and determined society, responsible only for brief intermittent mating; you are not ruled by instinct, Predestination or determinism.'

This novella's attention to the opposition of instinct and reason is signalled early in the piece, when William Adamson, dancing for the first time with Eugenia Alabaster (the woman he will woo and marry), felt the

> unmistakable stirrings and quickenings of bodily excitement in himself [...and] reflected – he was, after all, a scientist and an observer – that these dances were designed to arouse his desire in exactly this way [...] He remembered the palm-wine dance, a swaying circle which at a change in rhythm broke up into hugging couples who then set upon and danced round the one partnerless scapegoat dancer. He remembered being grabbed and nuzzled and rubbed and cuddled with great vigour by women with brown breasts glistening [...]
>
> Nothing he did now seemed to happen without this double vision, of things seen and done otherwise, in another world. (*A&I*, 6)

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19 A.S. Byatt, 'Ancestors', p. 80.

Instinct still has a power over the most rational characters: Joe Rose, Henry Perowne, William Adamson all behave, at times, in ways governed by instincts fashioned by our evolutionary development. What links these characters so strongly is the rational analysis of precisely those instinctive reactions. William thinks rationally on the causes of his bodily reaction, and goes on to see the cross-cultural universality (albeit with differences) of dance as part of courtship, implying without explicitly stating its biological basis in sexual selection. In this, he resembles Joe Rose when he proffers his socio-biological explanation (defence?) of why the men holding the ropes first held on and then, in the end, let go. Both men offer rationalized explanations of instinctive behaviour.

But William's reflection has, appropriately, a double meaning. On the one hand, William's 'reflection' is his rational consideration: later, in a piece of writing, the word is associated with other similar phrases, "'intelligence' – foresight, rational analysis, reflective thought" (*A&I*, 112), as opposed to 'instinct'. But William's reflection is also his mirror-image, the other half of his 'double vision', a William that 'sees and does things otherwise'. A little later, watching Harald (Eugenia's father) deliver his sermons leads William, via a circuitous route, to think of Amazonian ceremonies forbidden to women:

> He remembered the fleeing women, faces covered, sitting amongst the decorous English family, men on one side, women on another, watching Eugenia's pink tongue moisten her soft lips. He felt he was doomed to a kind of double consciousness. Everything he experienced brought up its contrary image from *out there*, which had the effect of making not only the Amazon ceremonies, but the English sermon, seem strange, unreal, of an uncertain nature. (*A&I*, 24)

William's double consciousness is the doubling that is brought about by metaphor, by analogy. It is, in effect, the double consciousness of the author – which, in the end, is what both Matty and William become. This double consciousness, is linked, for Byatt, to the way in which metaphorical or analogical 'vehicles' and 'tenors' are *mutually* affected. What William realises, listening to Harald's sermon, is that it is not only that the English sermon makes the Amazon seem Othered, but that the inverse also applies: the analogy is bi-directional. This is also what Matty sees in William's anthropomorphic descriptions of antheaps: on the one hand we describe them using the terms of human societies (workers and Queens), but on the other we also look to these insect societies as analogies for our own.

This double consciousness complicates simple analogies, and binary oppositions. We imagine, perhaps, that the Amazon might represent instinct, or pre-Lapsarian paradise, and indeed William almost says as much:

> And yet *that* is in so many ways the innocent, the unfallen world, the virgin forest, the wild people in the interior who are as unaware of modern ways – modern evils – as our first parents. There are strange analogies. Out there, no woman may touch a snake. (*A&I*, 30)

But William is also careful to point out that it is not so simple: "When I was in the Amazons, [...] I was haunted by an image of an English meadow in spring [...] It seemed to me that such scenes were *truly* Paradise" (Ibid.).

William is acutely aware of the interplay of instinct and rationality – the two worlds, in Amigoni's argument that I explored above, that humans inhabit. The extended analogy between humans and insects asks to what extent we may be governed by instinct as we might suppose the ant and bee colonies are – by the "blind compulsion" Joe Rose identifies in the insects in the soil. In particular, William's tendency, in his melancholy, to see himself as an ant within the Bredely Hall 'nest' can be read as representative of his lack of free will, and the determined nature of his life – a result, perhaps, of his instinctive sexual desire for Eugenia, to whom he is "bodily in thrall" (*A&I*, 105) in the strict sense of "bondage, servitude; captivity", just as Seth is in thrall to Dame Cottitoe Pan Demos in Matty's story 'Things Are Not What They Seem'.[20] William,

> like almost all his contemporaries, [...] was half afraid to give full expression, even to himself, of his very real sense that Instinct *was* Predestination, that he was a creature as driven, as determined, as constricted, as any flying or creeping thing. He wrote about will and reason, but they did not *feel* to him [...] to be very powerful or important entities. (*A&I*, 116)[21]

Elsewhere, however, William reveals an awareness of the complexity of the debate concerning instinct and rationality, or intelligence. In a piece of writing for the popular science, William "debate[s] with himself on paper" (*A&I*, 109) and concludes that the error may not be in the analogy between ourselves and the insects, but in seeing them as "automata [...] little mechanical

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20 thrall, *n.*[1] (*a.*[1]), *Oxford English Dictionary*, 2nd edn, 1989, *OED Online*, Oxford University Press <http://dictionary.oed.com/cgi/entry/50251567> [accessed 26 April 2010].

21 The "flying or creeping thing" may also recall to us the description of Satan in Book II of *Paradise Lost*: "So eagerly the fiend / Ore bog or steep, through strait, rough, dense, or rare, / With head, hands, wings, or feet pursues his way, / And swims or sinks, or wades, or creeps, or flyes". This echo would seem to link William's concerns regarding Predestination to the problems of Predestination at the heart of *Paradise Lost*.

inventions whirring about like clockwork in motion" (*A&I*, 110). Such a view wrongly leads to seeing ourselves as living a determined existence:

> The terrible idea [...] that we are *biologically predestined* like other creatures [...] treads softly behind the arrogant judgement that makes of the ant a twitching automaton. (*A&I*, 113)

Just as I showed with Joe Rose's narrative, William's is also affected in quite discrete ways by chance, by his instincts, and finally by his capacity for rationality. Initially, it is the traumatic contingency, to reuse Wood's phrase, of his shipwreck, and the loss of his specimens, that brings William to Bredely Hall and obliges him to stay, although his decision to do so is also affected by his desire for Eugenia. This desire is explicitly presented as irrational – in his journal after dancing with Eugenia William writes: "I believe I am a rational being", but a "kind of landslide [...] has taken place in my soul" (*A&I*, 13). Much later, in the same passage concerning Predestination and instinct quoted above, William notes that we may lose "the capacity to reason which makes us human [...] under the pressure of extreme desire" (*A&I*, 113).

In the end it is Matty Crompton who is the architect of "William's liberation from [the] trap" of seeing himself as an enslaved male ant, with no will beyond that of the nest.[22] Matty is associated with rationality as opposed to instinct – she is cerebral as Eugenia is bodily. Indeed, even as William begins to discern her intellect, he continues to see her as "a sexless being" – "She was *dry*, was Matty Crompton" (*A&I*, 105). But Matty's fable, 'Things Are Not What They Seem' (*A&I*, 119) hints at her own doubling. It is she that is the architect of his eventual freedom: it is at her suggestion that he begins to accompany her and the girls on nature walks and with her that he writes the popular science book that gives him financial independence from the Alabaster family. Indeed, Matty can be seen in some respects as a designer or author of William's narrative: during an anagram word game with the children Matty reveals her awareness of the incestuous relationship at the heart of Bredely Hall, receiving the word INSECT from William and returning it as INCEST. But the game also, as June Sturrock observes, shows William a way out of that society – the sequence of words (insect, incest, sphinx, phoenix) is William's story in little:

> First he must understand the relation between incest and insect—that is, he must see that Bredely Hall is, like the ant-hills, essentially an incestuous society [...] Only then is he enabled to see Matty as the sphinx who set him this liberating riddle [...] After this, he can liberate himself and become like the

[22] June Sturrock, 'Angels, Insects, and Analogy: A.S. Byatt's "Morpho Eugenia"', *Connotations*, 12 (2002/2003), 93-104 (p. 99).

> phoenix, reborn out of his own ashes.[23]

Speculating on the coincidence of the letters, William thinks:

> The luck of the letters was uncanny. It gave him the feeling that occasionally comes to most of us, that however we protest we are moved by chance, and struck by random shocks and blows, in fact there *is* Design, there is fate, it has us in its grip.
>
> It was possible, of course, that *she* had somehow shaped his cards. She liked riddles. (*A&I*, 153)

The three possibilities that William considers are chance, fate, or Matty's deliberate manipulation of the game. These are the factors, in this order, that shape William's wider narrative: initially contingency, then the 'grip' of his determined life at Bredely Hall, and finally Matty's deliberate intervention. As she modestly puts it, "I watch, and contrive, and write letters, and consider your nature" (*A&I*, 156). Matty represents, then, the power of rationality and free will to overcome the determinism of instinct – as Byatt says, if Eugenia was named "because the story was something to do with Sexual Selection as well as Natural Selection", Matty was invented as a character who is "not confined to her biological identity".[24] William is initially unable to see Matty's double identity, even though he is able to see his own. Early in the story, as he learns about Bredely Hall, William sees himself as "at once detached anthropologist and fairytale prince trapped by invisible gates and silken bonds in an enchanted castle" (*A&I*, 21), but does not imagine that Matty may also have an alter-ego. It is only at the end of the story that she can tell him "My name [...] is Matilda. Up here at night there is no Matty. Only Matilda." (*A&I*, 157).

* * * *

In *Saturday* a comparison of the epistemologies of science and literature is played out in two moments of conflict and their different resolutions. In *Enduring Love* the "cultural contest" between science and literature is expressed through the very different reactions of two characters to the same situation: Joe Rose is a popular science writer; his partner Clarissa a Keats scholar.[25]

Just as in *Saturday*, the narrative perspective of *Enduring Love* appears to privilege the scientific over the artistic. Rees-Jones claims that *Saturday* is "skewed towards, if not totally embracing, scientific rationalism", and Ian McEwan himself has said in interview that *Enduring Love* is in some ways a celebration of rationality: "I thought it was time to speak up for it [rationality]. I

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23 Sturrock, p. 99.
24 Byatt, 'True Stories and the Facts in Fiction', p. 117.
25 Amigoni, p. 154.

mean *Frankenstein* is the great anti-rational novel. [...] It's very hard to write a novel as fine as that in praise of rationality, but still I think one has to have a go".[26] McEwan also claims that in *Enduring Love* "the hero is rather super-endowed with a belief in rationality but he turns out to be right. And the reader, and the police, and his wife, are all wrong".[27] This may be true, but dangers attend a reading which sees *Enduring Love* as endorsing a hierarchy of knowledge with science and rationality at the top. I have shown how such a reading does not take account of complexities in the narrative of *Saturday*; similar details also undermine a simplistic binary reading of *Enduring Love*.

In *Saturday* the free indirect style expresses the thoughts of Perowne but nobody else, and in *Enduring Love* the autodiegetic narration, by Joe Rose, foregrounds his (scientific) beliefs; but in both cases the opinions of the protagonists are also presented for scrutiny. Our reading of both novels must pay attention to the authorial interrogation that attends this privileging. As Patricia Waugh has noticed, for example, *Enduring Love* often suggests that invoking science is a means of "disavowing personal responsibility or displacing difficulty of judgement with a fatalistic or deterministic perspective".[28] This certainly appears the case in the above example of Joe's scientific explanation for letting go of the rope. Not only is he "not prepared to accept that [he was the first to let go]" (*EL,* 14), but the tenor of his explanation does not even admit of a decision at all. Joe's description of "the mammalian conflict" (ibid.), of co-operation and selfishness as 'written' in our natures, absolves him of the responsibility for the decision to let go – the reason is buried in millennia of evolution, and in his nature. Even the moment of decision itself is something imposed from the outside: "The moment I glimpsed a body fall away [...] the matter was settled; altruism had no place" (*EL,* 15).

Joe's narration means that his own scientific perspective is overwhelmingly dominant in *Enduring Love*, even more so than Perowne's in *Saturday*; nonetheless there are moments in which McEwan provides an alternative perspective that reveals the problem with his scientific arrogance, and by extension "the dangers of imperialism and overreaching" of science more broadly.[29] One such insight comes from Jed Parry, whose own religious conviction is another example of an epistemology that forcibly excludes alternatives. In a letter to Joe he notes his reaction to Joe's popular science articles: "I hated you, Joe for your arrogance [...] There's never a moment's doubt or hesitation or admission of ignorance." (*EL,* 137) This criticism becomes even more pertinent when we combine it with Joe's own earlier admissions that the theory on which he hangs his

26 Koval, 'Ian McEwan'.
27 Ibid.
28 Waugh, p. 66.
29 Waugh, p. 65.

journalistic piece on narrative in science is "not one that [he] believed in necessarily" (*EL,* 48), and that "what [he] had written wasn't true. It wasn't written in pursuit of truth, it wasn't science." (*EL,* 50)

A more extended criticism of Joe's scientism comes from the second textual document in the novel. Clarissa's letter, reproduced as the penultimate chapter, is written in the aftermath of a row with Joe and gives a glimpse of her view of events, and an external perspective on Joe himself. The central criticism of Clarissa's letter is that Joe's scientific approach to the problem led him to some correct conclusions, but blinded him to other sorts of knowledge; or, as she puts it, "being right is not a simple matter" (*EL,* 216):

> You did the research, you made the logical inferences and you got a lot of things right, but in the process you forgot how to take me along with you, you forgot how to confide. (*EL,* 217)

In this description, Joe resembles a clichéd research scientist – doing the research, coming to the correct conclusions, but being unable to communicate with others. The irony, of course, is that Joe's recurrent fear is that he no longer carries out research, but merely communicates other people's conclusions.

Clarissa recognises that there are more kinds of knowledge that are relevant to the events of the novel than simply a diagnostic understanding of Parry and his likely actions:

> You were right, you acted decisively and you're right to take some pride in that. But what about the rest? – why it happened, how it changed you, how it might have been otherwise, what it did to us – that's what we've got now, and that's what we have to think about. (*EL,* 218)

Insofar as Clarissa stands for the literary and artistic epistemologies, she here espouses the importance of humanistic knowledge: the 'why', the counter-factuals, the impact on human relationships. There is a telling echo in Clarissa's "how is might have been otherwise", and in her letter in general, of Bernard Harrison's view of literature's epistemological role:

> Literature's role is not to impart Great Truths but to unhinge and destabilize them. What it has to say is never 'this is how it is' but always, rather, 'might it not be otherwise than an unwise and epistemic confidence leads you to think? Might it not be...like *this*?'[30]

[30] Harrison, p. 11.

In this letter Clarissa makes the argument for a broader epistemology than the exclusively scientific one with which we are presented through Joe's narration. Indeed, the autodiegetic narration is itself a critique of a monistic world-view: from within his narration we rarely get the opportunity to see Joe's behaviour from the outside, and as a result we are carried along by his own perception of his rationality. The image of Clarissa's face in the moment after Joe shoots Jed in the climactic scene, which "afflicted [Joe] during [his] sleepless night in the cell, and lingered for days afterwards", is a momentary insight:

> then I saw the expression on Clarissa's face. She was on her feet and she was staring at the gun in my hand with an expression of such repulsion and surprise that I thought we would never get past this moment. (*EL*, 214)

What Clarissa's expression exposes, for a moment, is that even if Joe does "turn out to be right", in some sense, his also is a mania, an obsession.[31] As Clarissa says, "[y]ou were manic, and driven, and very lonely" (*EL*, 217). With this realisation, we can identify Joe's obsessiveness elsewhere in the novel, his paranoia, and the parallels between Joe and Jed. Reading Jed's letters, Joe notes that he "learned how to scan these letters [...] linger[ing] only on the accusations or expression of frustration" (*EL*, 142); describing the veiled threats in the letters he says

> I wanted more than that. I longed for it. Please put the weapon in my hands, Jed. One little threat would have given me enough to take to the police, but he denied me, he played with me and held back, just as he said I did. [....] But he never mentioned his decision not to talk to me again, and I was suddenly bereft[.] (Ibid.)

The tone of longing here reveals, as Clarissa realises, that "He [Jed] brought something out in you [Joe]". Joe needs Jed, almost as much as Jed needs him:

> This was love's prison of self-reference but, joy or despair, I could not get him to threaten me, or even talk to me. Three times I crossed the street towards him with my hidden tape recorder turning, but he would not stay.
>
> 'Clear off then!' I shouted at his retreated back. [...] Come back and talk to me, was what I really meant. (*EL*, 143)

The "prison of self-reference" that Joe refers to is Jed's "world determined from the inside" in which he "illuminated the world with his feelings, and the world confirmed him at every turn his feelings took" (ibid.). Jed is "always scrutinising the physical world, its random placements and chaotic noise and colours, for correlatives of his current emotional state – and always finding satisfaction" (*EL*, 143); but the vocabulary here (physical world, chaotic noise, correlatives) reveals that this description could equally be of Joe's scientific scrutiny. Joe's rational approach,

[31] Koval, 'Ian McEwan'.

as Clarissa possibly sees, is in some ways as self-fulfilling as Jed's irrational one: "You saved my life, but perhaps you put my life in jeopardy – [...] by guessing his [Jed's] every move as if you were pushing him towards it." (*EL*, 218)

As Waugh realises, "McEwan [...] is writing in a tradition of British fiction that has always sought to subject scientific claims of epistemological exclusivity to its own broader conceptualisation of knowledge, reason and understanding".[32] Joe's constant recourse to science not only exempts him from examining his own responsibility, but also from the necessity of appreciating an alternative *emotional* system of understanding the world – how Clarissa sees the world – which instead he dismisses. His monocular scientific perspective, that the novel through its autodiegetic narration perfectly captures, is responsible for the breakdown in their relationship. Just as Clarissa's emotional perspective is associated with an artistic, as opposed to scientific, epistemology, Joe stands metonymically for the danger of a monistic scientific epistemology. Joe, as McEwan says, "turns out to be right", and Clarissa admits as much in her letter ("your being right", "however right you were", "you got a lot of things right", "you were right"); but even Joe finally realises that, firstly, "being right in this case was also to be contaminated by the truth", but more importantly that "there isn't only ever one system of logic" (*EL*, 214). It is epistemological pluralism, then, rather than simply rationality, that is endorsed by *Enduring Love*.

* * * *

In both *Enduring Love* and *Saturday* material held outside the narrative proper appears to make a claim for factual accuracy of these texts. With its appendix consisting of an apparent journal article "reprinted from the *British Review of Psychiatry*" (*EL*, 233) detailing Jed Parry's de Clérambault's syndrome, *Enduring Love* suggests that it is based on a real case history; meanwhile, in *Saturday* McEwan acknowledges, in detail, the importance of observing surgeons at work and the suggestions of a number of neurosurgeons, conspicuously including their qualifications: "Neil Kitchen MD FRCS (SN)". In both cases these post-scripts might appear to simply extend and confirm the perceived privileging of scientific rationalism in the narratives themselves.

But just as with the contestation of scientific priority that is presented within the narrative, we must be careful of simplification here. The acknowledgements in *Saturday* may suggest the importance of the medical and scientific details, but in the Vintage paperback edition these acknowledgements follow a copy of 'Dover Beach', reprinted for the easy reference of the reader: the juxtaposition should remind us of the equal importance of literature in the novel. Similarly,

[32] Waugh, p. 67.

the scientific case-study that ends *Enduring Love* is actually fictional – another example of the deceptive power of fictions to go alongside those of Daisy and Perowne. *Enduring Love*, as a piece of literature, draws its power from narrative, not from its foundation in actual events. In the end literature's power does not lie in its capacity for correspondence with reality at all: to judge literature in this way is to import a standard from a correspondence theory of truth that is perhaps irrelevant. As I will suggest in the conclusion which follows, literature's value may be precisely to question whether this is the only form of truth or knowledge that is valid.

7 Conclusion

In the preceding chapters I have examined the representation of determinism as it is affected by the conclusions and implications of two distinct fields of science, and as presented in two distinct genres of writing. Simplifying considerably, some broad conclusions can be drawn.

In the field of the new physics, universal determinism has been presented as collapsing under the weight of the new theories, particularly quantum indeterminacy. In the popular science writing on the subject, this argument has been emphasised rhetorically by a number of metaphors that distance the new physics from fully deterministic models (often associated with Laplace and Newton). Can we speculate as to the motivations for these specific representations? Firstly, it may be a response to widespread suspicion of deterministic models of the world, which may seem to contradict our perception of our free will. Part of the re-positioning of the new physics by these popular science texts involves foregrounding its connections with consciousness – both explicitly (asserting the importance of the consciousness of the experimenter), and implicitly (in metaphors that suggest the consciousness of elementary particles, for example). As a result the new physics is presented as congruent with our perception of the free will that consciousness seems to afford us. The combination of the connections established between the new physics and consciousness and the apparent demise of universal determinism as a result of the new physics seem, then, to suggest the greater compatibility of quantum mechanics with our sense of our capacity to affect the future, as compared with classical mechanics.

Such an argument would face significant logical counter-arguments, of course, not the least of which are whether the indeterminacy of quantum mechanics is ontological or merely epistemological, and whether the introduction of the random element of quantum states can 'save' free will from determinism anyway. But that is not the point – I am not suggesting that these popular science writers are trying, in their representation of quantum mechanics, to cut the complex Gordian knot of free will and determinism in a way that has any philosophical rigour. But it does seem that the *presentation* of the new physics in terms that associate it with consciousness not only make it less imposingly deterministic, but also more amenable to free will, and so to our human sense of the world. The details of quantum mechanics may be depicted as counter-intuitive, but the larger implications can be portrayed as closer (closer at least than those of universal determinism) to our common-sense view of the world.

The representation of the new physics in fiction and drama overlaps with that in popular science. Certainly the importance of consciousness is asserted as it is in popular science writing, but connected to this is a greater emphasis, compared to popular science, on the inherent uncertainty and limits of knowledge that the new physics seems to imply. This focus is motivated less by the desire to shift the focus to the human, than to highlight the incompleteness of scientific knowledge and perhaps to deny the total superiority of science as an epistemological system. That this is indeed the motivation is supported by the fact that many of these texts are also clearly engaging more broadly with the idea of the limits of knowledge and the difficulties in attaining it (as in *Copenhagen*, *Arcadia*, and *Gravity's Rainbow*).

It is tempting also to suggest a connection with narrative: that the appropriation of the idea of the demise of universal determinism at the hands of the new physics can be used to lend a narrative a sense of uncertainty. Narratives (with the rare exceptions of 'Choose You Own Adventure' books, or hypertexts[1]) are wholly determined, but our reading of them often involves the voluntary suppression of our knowledge of this fact: our fascination with narratives would seem to require the possibility of alternative sequences of events, alternative outcomes. The image of unpredictability associated with the quantum scale suggests this possibility.

More obviously, the implication of a limit on our ability to achieve a complete scientific description of the world that can be deemed to be a consequence of quantum indeterminacy, has been seized upon by some writers as analogical to the impossibility of complete knowledge in other areas, and also as representative of the essential incompleteness of scientific explanations. Both Stoppard and Frayn's plays conclude that there are just some things – human relations, ethics, motivations – that science may not be able to account for.

There are fields of the biological sciences, of course, that do indeed believe that their findings illuminate these areas. Popular accounts of genetics have certainly stressed the importance of genes in determining our behaviour. In popular science writing on evolution or genetics or (as very often) both, biological processes – the evolution of a species, the adaptation of a species, the development of an individual organism – are frequently presented in such a way as to suggest the determined or teleological nature of these processes. But whereas in popular physics texts the indeterminism implied in the texts' metaphors sits comfortably with the explicit contention of

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1 John Fowles's *The French Lieutenant's Woman* (London: Jonathan Cape, 1969), with its two alternative endings, might represent a rare literary example of the former category.

indeterminacy, the suggestion of a level of evolutionary inevitability or genetic determinism is at odds with the openly stated beliefs of these popular science writers.

For example, ostensibly it is almost universally accepted that genes are responsible for only a part of an organism's development, which is also affected by developmental processes on a molecular and cellular level, and on environmental conditions on both a molecular and organismal level. However, the representations of the role of genes in the development of the individual organism in popular science books suggest a level of genetic determinism: the metaphors used to describe genes, DNA and the expression of genes in the phenotype, not only emphasise the role that genes play, but also imply the simplicity and directness of the connection between genes and the phenotypic expression in the organism. Similarly, in representations of biological processes over evolutionary timescales a concealed suggestion of inevitability or determinism is to be found in the idea of evolution as a teleological process. Although many of the popular science books on evolution explicitly deny that evolution is progressive, asserting instead that it is simply adaptive to environmental and selective pressures, still the images used and the narratives constructed strongly suggest that evolution has been directed towards the current point, with particular emphasis on our own evolution as the necessary end point.

Suggesting possible motivations for these representations of evolution and genetics as deterministic processes may not be as straightforward as it is for the inverse pattern in popular physics texts. In the case of evolution there is presumably an anthropic principle at work – a desire to see our own existence as inevitable, necessary or as a culmination of evolution. (Of course, this is not to suggest here that the popular science writers are consciously guilty of such naivety, but that this anthropic bias nonetheless comes across in the representation of evolution.) In the case of genetics, determinism in its 'hard' form would not, I think, be any more popular a notion here than it is in physics, as genetic determinism would deny our free will just as would a 'clockwork universe'. However, in its 'soft' form – "it's in my genes" – this idea has become extremely pervasive. Clearly, the implication of a degree of determinism in representations of genetics enhances the importance of genetics as a discipline, but it may have its roots less in popular science than in public science.[2] As Van Dijck notes, funding for the HGP and for the wider study of genetics is predicated on the assumption that the results are of medical benefit.[3] In other words, genetics needs to show that it can be used to identify and treat disease. It is clear that strengthening the causal link between genes and the development of a particular trait (including disease) strengthens this case; stressing the contingency of developmental processes

2 See above, page 24, for the distinction between popular and public science.
3 See above, chapter 5, p. 101.

and the role of environmental pressures weakens it. Again, this argument does not require that these popular science writers are trying, consciously or not, to present this argument, only that they are utilising metaphors that have their origin in this strategic representation.

* * * *

I began this thesis by observing that it could hardly be contested that contemporary authors were influenced by scientific ideas, and furthermore that it is reasonable to infer that they may derive their knowledge of these currents in scientific thought from popular science books. In exploring how and, crucially, to what purpose scientific concepts have been incorporated into fiction I have found that these influences and appropriations are far from neutrally adopted. A central finding of my thesis is that these authors are not simply 'borrowing' from science, but are engaging with it on an epistemological level. In the texts that I have examined this often takes the form of a wariness of science as the dominant epistemological system.

Despite his public support for science and rationalism, Ian McEwan's novels, for example, are not universally sympathetic towards science: Joe Rose's actions are logical, but in the end questionable; Henry Perowne's scientific rationalism is set, in the novel, against the persuasive emotive effect of poetry and, in my reading, against the power of deception and fictionalising; and Michael Beard, the third in this trio of male scientist protagonists, is the least sympathetic character in a novel nearly devoid of sympathetic characters. Michael Frayn's *Copenhagen* and Tom Stoppard's *Arcadia* both enact the insufficiencies of science, portraying gaps in its explanatory capacity. In *Copenhagen* two icons of twentieth-century physics attempt to understand the motivations behind Heisenberg's earlier visit; but despite their repeated attempts, representative not only of the redrafting of a scientific paper but also the replication of scientific experiments, their methods cannot in the end reach any conclusion. In *Arcadia*, the mathematical research of Valentine parallels the literary research of Bernard, but both are frustrated by the 'noise' in the system. Like Stoppard, Thomas Pynchon introduces 'noise' into his narratives, which frustrates the rational efforts not only of his characters but also of his readers and critics.

These writers use the appropriations from science to criticise, or at least to question, science itself. Clearly, literature is not in a position to critique the veracity of the theories themselves: the questioning is not ontological, it is broader and epistemological. But what epistemological criticism can literature offer? It would seem that literature cannot stand alongside science as its epistemological equal if, firstly, we judge literature according to its capacity to contain truth or

knowledge and, secondly, we continue to use a conception of knowledge that is itself founded on a post-scientific correspondence theory of truth.

The first response, then, may be to choose to value literature on grounds other than that of truth. Lamarque and Olsen take this line: they argue that literary value should not be located in the truthfulness of literature, and that doing so reduces literature to a species of philosophy or social science. They are willing to accept that literature has the capacity to tell the truth, but deny that this is where literary value lies. As David Novitz summarises, "According to the 'no-truth' theory of literature that they [Lamarque & Olsen] defend, 'the concept of truth has no central or ineliminable role in critical practice' (p. 1), and it is simply false that literary works 'have the constitutive aim of advancing truths about human concerns' (p. 368)".[4] Instead, Lamarque and Olsen argue that the cognitive value of literary works lies "not in any truths that they might contain, but from their presentation, interpretation and development of themes (such as free will and determinism), which are assessed not in terms of truth but as more or less interesting".[5]

This characterisation of literature as presenting 'more or less interesting' interpretations of themes, but as having no role in the assessment of truth, reveals that such an argument assigns a role to literature that is, epistemologically, little more than a concession, leaving literature as insubstantial as compared to science or philosophy. This may not be considered a problem, but it is unclear where this leaves literature's engagements with science: is literature, then, simply parasitic on science for its truths, passively adopting an understanding of the world that is established by science? And if not, what can literature say about science that has epistemological validity?

Little better are some of the pro-truth arguments: Peter Mew, for example, proposes that literature's role in knowledge production might be to generate hypotheses that can be tested empirically by other disciplines.[6] But Carroll criticises this "hypothesis/confirmation approach", realising, correctly it seems to me, that "the concession here is at best grudging" since "hypotheses available from art and literature are, in general, woefully vague".[7] Additionally, it makes literature a second-order discipline, supplying ideas to be tested by the sciences.

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4 David Novitz, 'The Trouble with Truth', *Philosophy and Literature* 19 (1995), 350-59 (p. 351).

5 Alex Neill, review of Peter Lamarque and Stein Haugom Olsen, *Truth, Fiction and Literature: a Philosophical Perspective* in *The Philosophical Quarterly*, 47 (1997), 241-43 (p. 243).

6 Mew, pp. 329-37.

7 Carroll, p. 5.

More persuasive is Carroll's own argument that literature can fulfil a similar role to thought experiments in philosophy (what Daniel Dennett also calls 'intuition pumps'), reorganising cognitive elements that are already in place to bring about 'new' conclusions – new knowledge. Carroll focuses on what he calls 'virtue wheels' in novels, in which a variety of characters are presented with various virtues and vices and played through situations so that the reader can assess the relative virtues of each character. But it seems likely that this capacity of literature will be more effective in some areas (ethics, free will) than in others (ontology).

Of course, literary thought experiments need not be as constrained as philosophical or scientific ones. Alan Lightman's novella *Einstein's Dreams*, for example, is composed of a series of thought experiments.[8] It is simultaneously an exploration of possible understandings of time and also a comment on scientific method. The representation of time in each of the chapters is entirely fictional – indeed fantastical – and *Einstein's Dreams* does not explain Einstein's theories of time; but it does lead us, via a sequence of dream vignettes, to an appreciation of Einstein's new, counter-intuitive conception of time – particularly of its new relation to space. The book questions our preconceived common-sense view of time, in exactly the same way as did Einstein at the beginning of the twentieth century.

This is not to say that reading *Einstein's Dreams* gives the reader the same understanding of relativity as does grasping the mathematics of Einstein's special theory of relativity: the same truth is not contained in the novella as in the mathematical statement of the theory. But this may be precisely the point – the literary work does not provide the same sort of knowledge. Perhaps the rock on which pro-truth theories of literature founder is in taking a conception of truth that derives almost directly from a correspondence theory of truth. What *Einstein's Dreams* does instead is to ask 'might it not be like this?', to jettison correspondence with reality and present the counter-factual – in parallel with the way in which Einstein apparently began re-conceiving time.

It seems sensible, then, to acknowledge that literature does not contain truths of the same nature as scientific statements, and instead shift the grounds of the argument. Bernard Harrison does this, in his book *Inconvenient Fictions*, by asking us to change how we think about what sort of knowledge literature can impart to us. The broader project of this book is, simply put, to reconcile a critical humanism (the idea that literary texts have something to tell us about reality) with deconstructionism. He argues that although the undermining of logocentrism by deconstructionism is often thought to have brought about the downfall of critical humanism, it is rather a series of conclusions that are mistakenly believed to follow from deconstructionism that

8 Alan Lightman, *Einstein's Dreams* (New York: Pantheon Books, 1993).

oppose critical humanism.[9] Harrison attacks, in particular, 'formalism' (that the meaning of a text derives only from relationships within itself and with other texts, not with extra-textual elements) and 'textual solipsism' (that texts have no determinate meaning, that critics should not seek to explain them, and that texts are only about themselves and other texts). His attempt, then, is to construct a critical humanism that believes that it is possible to relate the textual to the extra-textual, but in ways that are not logocentric and are therefore reconcilable with deconstruction.

The reconciliation with deconstruction is not particularly relevant here – but the implications of Harrison's position are pertinent to the question I put above: 'can literature have an epistemological role in relation to science?'. Harrison's view is that current conceptions of knowledge all take a "Humean vision of knowledge as an amenity": "we take it for granted that the function of knowledge in general is not to change us but to enable us to master and change the world".[10] But there is an alternative, what Harrison calls 'dangerous knowledge': not knowledge as impersonal fact, but rather knowledge that has the power to change us by showing us that there are other perspectives than the ones that we previously considered – we see the "possibility that some truths about how things stand in the world may just not be accessible from the standpoint of a person with my present tastes, habits and assumptions; and may be accessible from the standpoint of a person differently constituted in those respects".[11]

In this view, then, literature does not 'represent' the world, or present us with truths about it; but instead can show us the limits of the ways in which we think about the world. "[T]heoretical knowledge, admirable and useful possession though it is, does not steadfastly or even very often call upon its possessors to question their own limitations as knowers", which, Harrison argues, is what literature can do:

> Literature's role is not to impart Great Truths but to unhinge and destabilize them. What it has to say is never 'this is how it is' but always, rather, 'might it not be otherwise than an unwise and hasty epistemic confidence leads you to think? Might it not be... like *this*?' [12]

We may want to disagree with some aspects of Harrison's argument, but the central tenets – that literature can show us firstly how things might be otherwise, and also remind us of the

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9 The logocentrism involved in wanting to see texts as 'truthful' lies in seeing propositions in literature as having an extra-textual, non-linguistic meaning – their having a 'centred' and 'grounded' meaning outside of the text and the language in which they are expressed, one that is not tied to the language of its expression.

10 Harrison, p. 4.

11 Harrison, p. 3.

12 Harrison, p. 6, p. 11.

unwiseness of epistemic over-confidence – are useful in this discussion of literature's epistemological relation to science. In this way literature might fulfil an important function within the field of knowledge production, a field dominated by science in our society; in fact, it is precisely this dominance that opens up the role for literature. Simply put, literature can act as a check to science.

I think that the analysis of contemporary British fiction in this study shows that these novelists and playwrights are doing precisely this: questioning the epistemic over-confidence of science, emphasising the incompleteness of scientific knowledge, utilising appropriations from scientific disciplines to ask whether science does actually have the capacity to form a complete description of the world, and acting – to quote Harrison again – "as a standing rebuke and irritant to the dominant paradigm of knowledge".[13]

The second important function that literature can fulfil is to draw attention to the language of science: clearly this also affords literature a rich opportunity in relation to popular science writing. This is not to go so far as to wonder, as Paul de Man does, whether it is even "certain that literature is a reliable source of information about anything but its own language", but rather to follow a different conclusion seemingly implied by the same essay and realise that literature can have an important role in revealing the workings of ideology – in this case, that of science.[14] As critics like Evelyn Fox Keller and Susan Oyama have shown with regards to genetics in the twentieth century, the language in which that field of science has expressed itself has had a formative effect on the path of its theory construction. As literature borrows concepts from science it can remind us, through its awareness of the polyvalency of the language in which it couches these appropriations, of the dangers of assuming that language can act as a neutral container for meaning, and the danger of allowing metaphors such as those that surround genetics to slip the bounds of their metaphoricity. For ultimately, the chapters on popular science in this thesis demonstrate that the language of popular science writing is worthy of the attention of literary scholars, and that such attention can identify the epistemological assumptions that underpin the metaphors and narratives deployed by these writers.

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13 Harrison, p. 4.

14 Paul de Man, *The Resistance to Theory* (Minneapolis: University of Minnesota Press, 1986), p.11.

Bibliography

Primary Texts

Popular Science books

Bryson, Bill, *A Short History of Nearly Everything* (London: Black Swan Books, 2004)

Capra, Fritjof, *The Tao of Physics* (London: Fontana, 1981)

Dawkins, Richard, *The Ancestor's Tale: A Pilgrimage to the Dawn of Evolution* (New York: Houghton Mifflin, 2004)

_____, *The Blind Watchmaker* (Harmondsworth: Penguin, 2000)

_____, *A Devil's Chaplain: Selected Essays* (London: Weidenfeld & Nicolson, 2003)

_____, *River Out of Eden* (New York: Basic Books, 1995)

_____, *The Selfish Gene* (Oxford: Oxford University Press, 1976)

_____, *The Selfish Gene*, 2nd edn (Oxford: Oxford University Press, 1989)

_____, *Unweaving the Rainbow: Science, Delusion and the Appetite for Wonder* (Harmondsworth: Penguin, 1998)

Einstein, Albert, and Leopold Infeld, *The Evolution of Physics* (Cambridge: Cambridge University Press, 1971)

Feynman, Richard P., *QED: The Strange Theory of Light and Matter* (London: Penguin, 1990)

Gleick, James, *Chaos: Making a New Science* (London: Vintage, 1998; first published 1987)

Gould, Stephen Jay, *Ever Since Darwin: Reflections in Natural History* (Harmondsworth: Penguin, 1980)

_____, *Life's Grandeur: The Spread of Excellence from Plato to Darwin* (London: Vintage, 2005; first published 1996)

_____, *Wonderful Life: The Burgess Shale and the Nature of History* (Harmondsworth: Penguin Books, 1991)

Gribbin, John, *In Search of Schrödinger's Cat* (London: Corgi Books, 1985)

Greene, Brian, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (London: Jonathan Cape, 1999)

Hofstadter, Douglas, *Gödel, Escher, Bach: An Eternal Golden Braid* (New York: Basic Books, 1979)

Küppers, Bernd-Olaf, *Information and the Origin of Life* (Cambridge, MA: MIT Press, 1990)

McFadden, Johnjoe, *Quantum Evolution* (London: HarperCollins, 2000)

Penrose, Roger, *The Emperor's New Mind: Concerning Computers, Minds and the Laws of Physics* (Oxford: Oxford University Press, 1989)

Peters, Ted, *Playing God?: Genetic Determinism and Human Freedom*, 2nd edn (New York: Routledge, 2002)

Pinker, Steven, *The Blank Slate* (Harmondsworth: Penguin, 2002)

Pollack, Richard, *Signs of Life: The Language and Meanings of DNA* (New York: Houghton Mifflin, 1994)

Ponomarev, L.I., *The Quantum Dice*, trans. by A.P. Repiev (Bristol, Philadelphia: Institute of Physics, 1993)

Ridley, Matt, *Nature via Nurture: Genes, Experience and What Makes Us Human* (London: Harper Collins, 2003)

_____, *The Red Queen: Sex and the Evolution of Human Nature* (Harmondsworth: Penguin, 1994)

Rose, Steven, R.C. Lewontin, Leon J. Kamin, *Not In Our Genes*: *Biology, Ideology and Human Nature* (Harmondsworth: Penguin, 1990)

Stewart, Ian, *Does God Play Dice?: The New Mathematics of Chaos*, 2nd edn (Harmondsworth: Penguin, 1997)

Watson, James, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* (London: Weidenfeld & Nicolson, 1968)

Zukav, Gary, *The Dancing Wu Li Masters* (London: Fontana, 1979)

Fiction

Amis, Martin, *Time's Arrow: or The Nature of the Offence* (Harmondsworth: Penguin, 1992)

Atwood, Margaret, *Cat's Eye* (London: Virago, 1990)

_____, *Oryx and Crake* (New York: Anchor Books, 2004)

Byatt, A.S., *Angels and Insects* (London: Chatto & Windus, 1992)

_____, *On Histories and Stories: Selected Essays* (London: Chatto & Windus, 2000)

_____, *A Whistling Woman* (London: Chatto & Windus, 2002)

Fowles, John, *The French Lieutenant's Woman* (London: Jonathan Cape, 1969)

Frayn, Michael, *Copenhagen* (London: Methuen, 2000)

Ishiguro, Kazuo, *Never Let Me Go* (London: Faber and Faber, 2005)

Lightman, Alan, *Einstein's Dreams* (New York: Pantheon Books, 1993)

McEwan, Ian, *Enduring Love* (London: Vintage, 1998; first published 1997)

_____, *Or Shall We Die?: Words for an oratorio set to music by Michael Berkeley* (Jonathan Cape: London, 1983)

_____, *Saturday* (London: Vintage, 2006; first published 2005)

_____, *Solar* (London: Jonathan Cape, 2010)

Mitchell, David, *Cloud Atlas* (London: Hodder and Stoughton, 2004)

Pynchon, Thomas, *The Crying of Lot 49* (London: Vintage, 2000; first published 1967)

_____, *Gravity's Rainbow* (New York: Viking, 1978; first published 1973)

_____, *Gravity's Rainbow* (Harmondsworth: Penguin, 1987; first published 1973)

_____, *Gravity's Rainbow* (London: Vintage, 2000; first published 1973)

Stoppard, Tom, *Arcadia* (London: Faber, 1993)

_____, *Hapgood* (London: Faber, 1988)

Secondary Texts

Abbott, H. Porter, *The Cambridge Introduction to Narrative*, 2nd edn (Cambridge: Cambridge University Press, 2008)

Adams, Douglas, *The Hitchhiker's Guide to the Galaxy* (London: Gollancz, 2002; first published 1979)

Amigoni, David, '"The Luxury of Storytelling": Science, Literature and Cultural Contest in Ian McEwan's Narrative Practice' in *Science and Literature*, ed. by Sharon Rushton (English Association: Boydell and Brewer, 2008), pp.151-67

Antor, Heinz, 'The Arts, the Sciences, and the Making of Meaning: Tom Stoppard's *Arcadia* as a Post-Structuralist Play', *Anglia*, 116 (1998), 326-54

Atwood, Margaret, 'An interview with Margaret Atwood', <http://www.oryxandcrake.co.uk/interview.asp> [accessed 8 April 2010].

_____, 'Brave New World', review of Kazuo Ishiguro, *Never Let Me Go* in *Slate* (1 April 2005) <http://www.slate.com/id/2116040> [accessed 10 April 2010]

_____, 'Further Reading' <http://www.oryxandcrake.co.uk/furtherreading.asp> [accessed 10 April 2010]

_____, 'Perfect Storm: Writing *Oryx and Crake*' <http://www.oryxandcrake.co.uk/perfectstorm.asp> [accessed 10 April 2010]

Barad, Karen, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007)

Barfield, Steven, 'Dark matter: The controversy surrounding Michael Frayn's *Copenhagen*', *Archipelago*, 8.3 (2004), 80-103

Barnett, David, 'Reading and Performing Uncertainty: Michael Frayn's *Copenhagen* and the Postdramatic Theatre', *Theatre Research International*, 30 (2005), 139-49

Barrow, John D., and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986)

Barton, Ruth, 'Just Before *Nature*: The Purposes of Science and the Purposes of Popularization in some English Popular Science Journals of the 1860s', *Annals of Science*, 55 (1998), 1-33

Basalla, George, 'Pop Science: The Depiction of Science in Popular Culture', *Science and its Public: The Changing Relationship,* ed. by Gerald Holton and William A. Blanpied, *Boston Studies in the Philosophy of Science,* 33 (Dordrecht: D. Reidel, 1976), 260-78

Baxandall, Michael, *Shadows and Enlightenment* (New Haven: Yale University Press, 1995)

Beer, Gillian, *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot, and Nineteenth-Century Fiction* (London: Routledge, 1983)

_____, *Open Fields: Science in Cultural Encounter* (Oxford: Clarendon, 1999)

Bensaude-Vincent, Bernadette, 'In the Name of Science', *Science in the Twentieth Century,* ed. by John Krige and Dominique Pestre (Amsterdam: Harwood Academic Publishers, 1997)

Black, Max, *Models and Metaphors: Studies in Language and Philosophy* (Ithaca, New York: Cornell University Press, 1962)

Bodmer, Walter, and Robin McKie, *The Book of Man: The Human Genome Project and the Quest to Discover our Genetic Heritage* (New York: Scribner, 1995)

Borges, Jorge Luis, 'On Exactitude in Science' in *Collected Fictions*, trans. by Andrew Hurley (London: Penguin, 1999)

Bowler, Peter J., *Science for All: The Popularization of Science in Early Twentieth-Century Britain* (Chicago: University of Chicago Press, 2009)

Bricmont, Jean, 'Determinism, Chaos and Quantum Mechanics', <http://www.freeinfosociety.com/pdfs/mathematics/determinism.pdf> [accessed May 23 2007]

_____, 'Science of Chaos of Chaos in Science?', *Physicalia Magazine*, 17 (1995), <http://www.chronos.msu.ru/EREPORTS/bricmont.htm> [accessed 24 May 2007]

Brock, W.H., 'The Development of Commercial Science Journals in Victorian Britain' in *Development of Science Publishing in Europe*, ed. by A.J. Meadows (Amsterdam: Elsevier, 1980), 95-122

Brockman, John, *The Third Culture* (New York: Simon & Schuster, 1995)

Broks, Peter, *Understanding Popular Science* (Maidenhead: Open University Press, 2006)

Burnham, John C., *How Superstition Won and Science Lost: Popularizing Science and Health in the United States* (New Brunswick: Rutgers University Press, 1987)

Carroll, Noel, 'The Wheel of Virtue: Art, Literature and Moral Knowledge', *The Journal of Aesthetics and Art Criticism*, 60 (2002), 3-26

Clark, Ronald W., *Einstein: The Life and Times* (New York: HarperCollins, 1971)

Cloître, Michel, and Terry Shinn, 'Expository Practice: Social, Cognitive and Epistemological Linkage' in *Expository Science: Forms and Functions of Popularisation* ed. by Terry Shinn and Richard Whitley, *Sociology of the Sciences Yearbook 9* (Dordrecht: D. Reidel, 1985), 31-60

Corballis, Richard, *Stoppard: The Mystery and the Clockwork* (Oxford: Amber Lane Press, 1984)

Curtis, R., 'Narrative Form and Normative Force: Baconian Story-telling in Popular Science', *Social Studies of Science*, 24 (1994), 419-61

Darwin, Charles, *The Origin of Species*, ed. and intro. by J.W. Burrow (Harmondsworth: Penguin Classics, 1968)

_____, *The Origin of Species: A Variorum Text*, ed. by Morse Peckham (Philadelphia: University of Pennsylvania Press, 1959)

Dawkins, Richard, 'Sociobiology: The debate continues', review of Rose, Lewontin & Kamin, *Not In Our Genes* in *New Scientist*, 24 January 1985, 59-60

de Man, Paul, *The Resistance to Theory* (Minneapolis: University of Minnesota Press, 1986)

Denison, Paul, 'Morality Play: Brilliant Minds or Mad Bombers?' *The Register-Guard*, 3 April 2005, G5.

Dolby, R.G., 'The Transmission of Science', *History of Science*, 15, 1 (1977), 1-43

Downes, Stephen M., review of Susan Oyama, *The Ontogeny of Information* in *Perspectives in Biology and Medicine*, 44 (2001), 464-69

Earman, John, *A Primer on Determinism* (Dordrecht: D. Reidel, 1986)

Egers, Martin, 'Hermeneutics and the New Epic of Science' in *The Literature of Science: Perspectives on Popular Science Writing*, ed. by Murdo William McRae (Athens: University of Georgia Press, 1993), 187-209

Eldredge, N., and S.J. Gould, 'Punctuated Equilibria: An alternative to phyletic gradualism' in *Models in Paleobiology*, ed. by T.J.M. Schopf (San Francisco: Freeman Cooper, 1972), pp. 82-115

Fedoroff, Nina V., Nancy Marie Brown, *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods* (Washington, DC: Joseph Henry Press, 2004)

Fleming, John, *Stoppard's Theatre: Finding Order Amid Chaos* (Austin: University of Texas Press, 2001)

Frayn, Michael, 'Friends and Mortal Enemies', *Guardian*, 23 March 2002, *Saturday Review* <http://www.guardian.co.uk/Archive/Article/0,4273,4379725,00.html> [accessed 3 April 2009]

_____, *Stage Directions: Writing on Theatre 1970-2008* (London: Faber, 2008)

Freud, Sigmund, *The Standard Edition of the Complete Psychological Works*, trans. and ed. by James Strachey, 24 vols, (London: Hogarth Press, 1953-1974)

Fuller, Steve, *Science* (Buckingham: Open University Press, 1997)

Gamow, George, 'On information transfer from nucleic acids to proteins', *Det Kongelige Danske Videnskabernes Selskab: Biologiske Meddelelser*, 22 (1955), 1-7

Golinski, Jan, *Making Natural Knowledge: Constructivism and the History of Science* (Cambridge: Cambridge University Press, 1998)

Gould, Stephen Jay, 'Self-Help for a Hedgehog Stuck on a Molehill', *Evolution*, 51 (1997), 1020-23

Gregory, Jane, and Steve Miller, *Science in Public: Communication, Culture and Credibility* (Cambridge, MA: Basic Books, 2000)

Grundmann, Reiner, and Jean-Pierre Cavaillé, 'Simplicity in Science and its Publics', *Science as Culture*, 9 (2000), 353-89

Hansen, Arlen J., 'The Dice of God: Einstein, Heisenberg, and Robert Coover', *NOVEL: A Forum on Fiction*, 10, Tenth Anniversary Issue: I (1976), 49-58

Harrison, Bernard, *Inconvenient Fictions: Literature and the Limits of Theory* (New Haven: Yale University Press, 1991)

Hessenbruch, Arne, (ed.), *Reader's Guide to the History of Science* (London: Fitzroy Dearborn, 2000)

Hilgartner, Stephen, 'The Dominant View of Popularization: Conceptual Problems, Political Uses', *Social Studies of Science*, 20 (1990), 519-39

Hoefer, Carl, 'Causal Determinism', The Stanford Encyclopedia of Philosophy, Spring 2010 Edition, ed. by Edward N. Zalta <http://plato.stanford.edu/archives/spr2010/entries/determinism-causal/> [accessed 10 May 2010]

Holten, Gerald, Jonathan Logan, Michael Frayn and Thomas Powers, '*Copenhagen*: An Exchange', *New York Review of Books*, 11 April 2002 <http://www.nybooks.com/articles/15264> [accessed 23 March 2009]

Hubbard, Ruth, and Elijah Wald, *Exploding the Gene Myth: How Genetic Information is Produced and Manipulated by Scientists, Physicians, Employers, Insurance Companies, Educators, and Law Enforcers* (Boston: Beacon Press, 1993)

Jernigan, Daniel, 'Tom Stoppard and "Postmodern Science": Normalizing radical Epistemologies in *Hapgood* and *Arcadia*' in *Comparative Drama*, 37 (2003), 3-35

Jurdant, Baudouin, 'Popularization of Science as the Autobiography of Science', *Public Understanding of Science*, 2 (1993), 365-73

Keller, Evelyn Fox, *Refiguring Life: Metaphors in Twentieth-Century Biology* (New York: Columbia University Press, 1995)

King, Robert L., 'The Play of Uncertain Ideas', *The Massachusetts Review*, 42 (2001), 165-75

Knight, David M., *Natural Science Books in English, 1600-1900* (London: Batsford, 1972)

_____, 'Scientists and their Publics: Popularization of Science in the Nineteenth Century' in *The Cambridge History of Science, Volume 5: The Modern Physical and Mathematical Sciences*, ed. by Mary Jo Nye (Cambridge: Cambridge University Press, 2003)

Knusden, Susanne, 'Scientific metaphors going public', *Journal of Pragmatics*, 35 (2003), 1247-63

Koval, Ramona. 'Ian McEwan', Books and Writing (Radio National), 22 September 2002 <http://www.abc.net.au/rn/arts/bwriting/stories/s679422.htm> [accessed 8 March 2010]

Kramer, Jeffrey, and Prapassaree Kramer, 'Stoppard's *Arcadia*: Research, Time, Loss' in *Modern Drama*, 40 (1997), 1-10

Kuhn, Thomas S., *The Structure of Scientific Revolutions*, 2nd edn (Chicago: University of Chicago Press, 1970)

Lakatos, Imre, *Proofs and Refutations: The Logic of Mathematical Discovery*, ed. by John Worrall and Elie Zahar (Cambridge: Cambridge University Press, 1976)

Lamarque, Peter, and Stein Haugom Olsen, *Truth, Fiction, and Literature: A Philosophical Perspective* (Oxford: Clarendon, 1994)

Laplace, Pierre Simon Marquis de, *A Philosophical Essay on Probabilities*, trans. by Frederick Wilson Truscott and Frederick Lincoln Emory from the sixth French edition (New York: John Wiley & Sons, 1902)

Leane, Elizabeth, *Reading Popular Physics: Disciplinary Skirmishes and Textual Strategies* (Aldershot: Ashgate, 2007)

Levins, R., & R.C. Lewontin, *The Dialectical Biologist.* (Cambridge, MA.: Harvard University Press, 1985)

Lewontin, R.C., *Human Diversity* (San Francisco: Scientific American, 1982)

_____, *It Ain't Necessarily So: The Dream of the Human Genome and Other Illusions* (London: Granta, 2000)

_____, 'The Organism as the Subject and Object of Evolution' *Scientia*, 118 (1983), 65–82

Mandelbrot, Benoit, *The Fractal Geometry of Nature* (New York: W. H. Freeman, 1982)

Medawar, P.B., 'Is the Scientific Paper a Fraud?', in P.B. Medawar, *The Threat and the Glory: Reflections on Science and Scientists* (New York: HarperCollins, 1990), pp. 228-33

Meisel, Martin, *How Plays Work: Reading and Performance* (Oxford: Oxford University Press, 2007)

Melbourne, Lucy, '"Plotting the Apple of Knowledge": Tom Stoppard's *Arcadia* as Iterated Theatrical Algorithm', *Modern Drama*, 41 (1998) 557-72

Mew, Peter, 'Facts in Fiction', *The Journal of Aesthetics and Art Criticism*, 31 (1973), 329-37

Midgley, Mary, 'Gene-Juggling', *Philosophy*, 54 (1979), 439-58

_____, 'Selfish Genes and Social Darwinism', *Philosophy*, 58 (1983), 365-77

Morange, Michel, *The Misunderstood Gene*, trans. Matthew Cobb (Cambridge, MA: Harvard University Press, 2001)

Moss, Lenny, 'The Meanings of the Gene and the Future of the Phenotype', *Genomics, Society and Policy*, 4 (2008), 38-57

_____, *What Genes Can't Do* (Cambridge, MA: MIT Press, 2003)

Müller-Muth, Anja, '"It's wanting to now that makes us matter": Scepticism or Affirmation in Tom Stoppard's *Arcadia*', *Connotations*, 12:2-3 (2002/2003), 281-91

Myers, Greg, 'Discourse Studies of Scientific Popularization: Questioning the Boundaries', *Discourse Studies*, 5 (2003), 265-79

_____, 'Making a Discovery: Narratives of Split Genes' in *Narrative in Culture: The Uses of Storytelling in the Sciences, Philosophy and Literature*, ed. by Christopher Nash (London: Routledge, 1990), pp.102-26

Neill, Alex, review of Peter Lamarque and Stein Haugom Olsen, *Truth, Fiction and Literature: a Philosophical Perspective* in *The Philosophical Quarterly*, 47 (1997), 241-43

Niederhoff, Burkhard, '"Fortuitous Wit": Dialogue and Epistemology in Tom Stoppard's *Arcadia*', *Connotations*, 11 (2001-2), 42-59

_____, 'Who Shot the Hare in Stoppard's *Arcadia*? A reply to Anja Müller-Muth', *Connotations*, 13:1-2 (2003/2004) 170-78

Norton, J.D., 'Causation as Folk Science', *Philosopher's Imprint*, 3:4 (2003), 1-22 <http://www.philosophersimprint.org/003004/> [accessed 12 May 2010]

Novitz, David, 'The Trouble with Truth', *Philosophy and Literature*, 19 (1995), 350-59

Oyama, Susan, *The Ontogeny of Information: Developmental Systems and Evolution*, 2nd edn (Durham, NC: Duke University Press, 2000)

Oxford English Dictionary, 2nd edn, 1989, *OED Online*, Oxford University Press, <http://www.oed.com/>

Paley, William, *Paley's Watchmaker: An Abridged Version of William Paley's Natural Theology*, ed. and intro. by Bill Cooper (Chichester: New Wine Press, 1997)

Paul, Danette, 'Spreading Chaos: The Role of Popularizations in the Diffusion of Scientific Ideas', *Written Communication*, 21 (2004), 32-68

Plato, *The Republic*, trans. by Benjamin Jowett (New York: Cosimo, 2008; this translation first published 1894)

Rees-Jones, Deryn, 'Fact and Artefact: Poetry, Science, and a Few Thoughts on Ian McEwan's *Saturday*', *Interdisciplinary Science Reviews*, 30 (2005), 331-40

Restivo, Sal, 'Parallels and Paradoxes in Modern Physics and Eastern Mysticism: I – A Critical Reconnaissance', *Social Studies of Science*, 8 (1978), 143-81

_____, 'Parallels and Paradoxes in Modern Physics and Eastern Mysticism: II – A Sociological Perspective on Parallelism', *Social Studies of Science*, 12 (1982), 37-71

Richards, I.A., *The Philosophy of Rhetoric*, ed. John Constable (London: Routledge, 2001; first published 1936)

Ridley, Matt, 'What Makes You Who You Are: Which is stronger—nature or nurture?', *TIME Magazine* (Sunday, 25 May 2003)

Roof, Judith, *The Poetics of DNA* (Minneapolis: University of Minnesota Press, 2007)

Rose, Paul Lawrence, and Thomas Powers (reply), 'Copenhagen Cont'd.', *The New York Review of Books*, 9 May 2002 <http://www.nybooks.com/articles/15373> [accessed 23 March 2009]

Rousseau, G.S., 'Science Books and their Readers in the Eighteenth Century', in *Books and their Readers in Eighteenth-Century England* ed. by Isabel Rivers (Leicester: Leicester University Press, 1982), pp. 197-255

Rowe, M.W., 'Lamarque and Olsen on Literature and Truth', *The Philosophical Quarterly*, 47 (1997), 322-41

Schrödinger, Erwin, *What Is Life?* (Cambridge: Cambridge University Press, 1944)

Shakespeare, William, *The Complete Works*, Compact Edition, ed. by Stanley Well and Gary Taylor (Oxford: Clarendon Press, 1994)

Sheets-Pyenson, Susan, 'Popular Science Periodicals in Paris and London: The Emergence of a Low Scientific Culture, 1820-1875', *Annals of Science*, 42 (1985), 549-72

Snow, C.P., *The Two Cultures* (Cambridge: Cambridge University Press, 1993)

Strehle, Susan, *Fiction in the Quantum Universe* (Chapel Hill: University of North Carolina Press, 1992)

Sturrock, June, 'Angels, Insects, and Analogy: A.S. Byatt's "Morpho Eugenia"', *Connotations*, 12 (2002/2003), 93-104

Turner, Frank M., 'Public Science in Britain 1880-1919', *Isis*, 71 (1980), 589-601

Turney, Jon, 'More Than Story-Telling: Reflecting on Popular Science' in *Science Communication in Theory and Practice,* ed. by Susan M. Stocklmayer, Michael M. Gore and Chris Bryant (Dordrecht: Kluwer Academic Publishers, 2001), pp. 47-62

_____, 'Science communication in fiction' in *Practising Science Communication in the Information Age*, ed. by Richard Holliman, Jeff Thomas, Sam Smidt, Eileen Scanlon, and Elizabeth Whitelegg (Oxford: Oxford University Press, 2008), pp. 166-77

Van Dijck, José, *Imagenation: Popular Images of Genetics* (Basingstoke: Macmillan, 1998)

Waugh, Patricia, 'Science and Fiction in the 1990s' in *British Fiction of the 1990s*, ed. by Nick Bentley (Abingdon: Routledge, 2005), pp. 57-77

Whitley, Richard, 'Knowledge Producers and Knowledge Acquirers: Popularisation as a Relation Between Scientific Fields and Their Publics' in *Expository Science: Forms and Functions of Popularisation* ed. by Terry Shinn and Richard Whitley, *Sociology of the Sciences Yearbook 9* (Dordrecht: D. Reidel, 1985), 3-28

Whitworth, Michael H., 'The Clothbound Universe: Popular Physics Books, 1919-1939', *Publishing History*, 40 (1996), 53-82

_____, *Einstein's Wake: Relativity, Metaphor and Modernist Literature* (Oxford: Oxford University Press, 2001)

Wood, James, 'The Human Difference', review of Kazuo Ishiguro, *Never Let Me Go* in *The New Republic Online* (12 May 2005) <http://www.powells.com/review/2005_05_12.html> [accessed 10 April 2010]

_____, 'James Wood writes about the manipulations of Ian McEwan', *London Review of Books*, 30 April 2009, pp.14-16.

Wu, Duncan, *Making Plays: Interviews with Contemporary British Dramatists and Directors* (Basingstoke: Macmillan 2000)