Rhetoric and Representation:

Exploring the Cultural Meaning of the Natural Sciences in Contemporary Popular Science Writing and Literature

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Abstract

During the last twenty-five years, literary critics have become increasingly aware of the complexities surrounding the relationship between the so-called two cultures of science and literature. Instead of regarding them as antagonistic endeavours, many now argue that the two emerge from the common ground of language, and often deal with and respond to similar questions, although their methods of doing it are different. While this thesis does not suggest that science should simply be treated as an instance of discursive practices, it shows that our understanding of scientific ideas is to a considerable extent guided by the employment of linguistic structures that allow genres of science writing such as popular science to express arguments in a persuasive manner. In this task figurative language plays a significant role, as it helps create a close link between content and form, the latter not only stylistically supporting the former but also frequently epitomizing the philosophy behind what is said and establishing various kinds of argumentative logic. As many previous studies have tended to focus only on the use of metaphor in scientific arguments, this thesis seeks to widen the scope by also analysing the use of other figures of speech.

Because of its important role in popular science writing, figurative language constitutes a bridge to literature employing scientific ideas. While popular science employs figurative language to enhance its rhetoric and literary qualities, such literature portrays science by using its own techniques of representation, with the rhetoric of popularized accounts evident in the portrayals. By a comparative analysis of contemporary popular science writing and literature, this study discusses how the two often reciprocally affect each other's means of representation while approaching shared topics, such as identity and knowledge, thus together contributing to the process of signification through which scientific ideas are given their human meaning and relevance.

Contents

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1. Introduction

1.1 From the Two Cultures Debate towards a Third Culture

Studies focusing on some of the various aspects of the relationship between science and literature often begin by referring to the so-called two cultures debate, and — for better or worse — mine is no exception. Of its various historical manifestations such as the publication of Jonathan Swift's satire on the discussion on the merits of classical and modern learning in *The Battle of the Books* in 1704,[1] the clash of Romanticism and Classicism in the late eighteenth and early nineteenth centuries,[2] the exchange of views between Matthew Arnold and T. H. Huxley at the end of the nineteenth century,[3] the Two Cultures debate between C. P. Snow and F. R. Leavis in the 1960s, and the Science Wars of

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[1] Swift attacks the battle between the so-called Ancients and Moderns, which originated at the end of the seventeenth century with the publication of Sir William Temple's *Of Ancient and Modern Learning* (1690). This debate primarily concerned the question about the value given to two different kinds of knowledge: the backward-looking Renaissance humanism and the forward-looking natural philosophy, or science. Siding with the Ancients, Swift criticizes science for its attempt to monopolize truth. John H. Cartwright and Brian Baker, *Literature and Science: Social Impact and Interaction*, Science and Society: Impact and Interaction (Santa Barbara: ABC-CLIO, 2005), p. 267. Further references to this book are given in parenthesis.

[2] Like the battle between the Ancients and the Moderns, this one rose from the question concerning the truth-value of two different types of knowledge: the 'emotional, aesthetic, and moral truths' of Romantic poetry and the 'factual truths' (Cartwright and Baker, p. 270) of Enlightenment science.

[3] The Huxley-Arnold debate links the question of knowledge to that of education. While the biologist Huxley spoke for the importance of science for education, the poet and critic Arnold thought that the learning of languages and literature should form its core (Cartwright and Baker, p. 270).

the 1990s,[4] it is perhaps the last but one that serves as the proper starting point for my own discussion. The intense dispute between Snow and Leavis was sparked off by the famous lecture given by the former in Cambridge in 1959, 'The Two Cultures and the Scientific Revolution', in which the novelist-scientist argued that the cultural climate of post-war Britain was characterized by a division into two antagonistic paradigms of thought: in Snow's view the technologically progressive world of science stood in opposition to the conservative thinking of the humanities, with little communication going on between the two.[5] Snow aimed his main criticism at literary intellectuals, who in his opinion failed to recognize the role of science as a fundamental force in society, thus implying that the natural sciences were less valuable than literature and the arts in the eyes of the country's literary intellectuals.[6] Moreover, the lecture closely linked the question of the cultural value of scientific knowledge to the critique of the British education system, whose emphasis on specialization Snow saw as further contributing to the split.[7] This shows that instead of arguing about what an ideal culture should look like, Snow and Leavis were attacking each other over the educational means of attaining that culture (Cordle, pp. 15–16).

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[4] As the name implies, the latest stage of the two cultures debate, the so-called Science Wars, took the discussion to a whole new level, particularly with its extremely heated nature. Generally speaking, the Science Wars in all its complexity was a debate between two types of views of science: realist and constructivist. While the proponents of the realist view of science accused the academic left of needlessly criticizing science for political and ideological ends (see, for instance, *Higher Superstition: The Academic Left and Its Quarrels with Science* (Baltimore: The Johns Hopkins University Press, 1994) by Norman Levitt and Paul Gross), the constructivists defended themselves by insisting that the realists lacked proper understanding of schools of thought such as poststructuralism and social constructivism.

[5] Patricia Waugh, 'Revising the Two Cultures Debate: Science, Literature, and Value', in *The Arts and Sciences of Criticism*, ed. by David Fuller and Patricia Waugh (Oxford: Oxford University Press, 1999), pp. 33–59 (pp. 33–34).

[6] Waugh, 'Revising the Two Cultures Debate', pp. 33–59 (pp. 33–34).

[7] Daniel Cordle, *Postmodern Postures: Literature, Science and the Two Cultures Debate* (Aldershot: Ashgate, 1999), pp. 15–16. Further references to this book are given in parenthesis.

Four years later, in an expanded essay version of the original lecture titled *The Two Cultures: And a Second Look* (1963), Snow made a prediction concerning an emerging third culture that would facilitate a creative exchange of ideas between literary intellectuals and scientists. Discussing the role of social sciences in the two cultures debate, he argued that they might function as a bridge between the views of the natural sciences and the humanities.[8] Snow decided to label this intermediary space 'social history', which was to include representatives from fields as diverse as sociology, demography, political science, economics, psychology, medicine, architecture, and so forth. Although we can retrospectively see that the third culture never quite materialized in the way Snow predicted it would — writing during the Science Wars in 1996, the mathematician Alan Sokal noted that the worlds of the natural sciences and the humanities 'are probably farther apart in mentality than at any time in the past 50 years'[9] — it is nevertheless possible to observe the emergence of a slightly different kind of third culture. The editor John Brockman notes in his introduction to *The Third Culture: Beyond the Scientific Revolution* (1995), a collection of essays by notable scientists on the major questions of contemporary science, that instead of communicating with the 'quarrelsome mandarin class' ('Third Culture') of literary intellectuals, many professional scientists are now concerned with expressing their thoughts to audiences that have little or no scientific training through the medium of popular science books. In fact, it could be argued, as John Carey, the editor of *The Faber Book of Science*

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[8] John Brockman, 'Introduction: The Emerging Third Culture', in *The Third Culture: Beyond the Scientific Revolution*, ed. by John Brockman (New York: Simon & Schuster, 1995) <http://www.edge.org/documents/ThirdCulture/f-Introduction.html> [accessed 11 January 2005]. Further references to this chapter are given in parenthesis.

[9] Alan Sokal, 'Transgressing the Boundaries: An Afterword', *Dissent*, 43.4 (1996), 93–99 (p. 94).

(1995), does, that there has been both a quantitative and qualitative explosion of popular science from the 1960s onwards.[10] Writers who are either practising scientists themselves or who have an education in the natural sciences — such as Isaac Asimov, Oliver Sacks, Bill Bryson, Arthur C. Clarke, Paul Davies, Lewis Thomas, Carl Sagan, Steven Weinberg, Richard Feynman, Stephen Jay Gould, Peter Medawar, Stephen Hawking, James Watson, and Richard Dawkins — have placed profound scientific ideas within the reach of readers who cannot be expected to learn about science by perusing scientific research articles. Consequently, as Carey puts it, contemporary popular science writing has become 'a new kind of late twentieth-century literature, which demands to be recognized as a separate genre'.[11]

The importance of this massive genre has for some time been also recognized by literary critics and scholars. For instance, Murdo William McRae, the editor of the essay collection *The Literature of Science: Perspectives on Popular Scientific Writing* (1993), observes that contrary to the notion that such writing is merely a simplified form of the more technical expositions, 'science popularizations are anything but intellectually jejune'.[12] Although they lack the technical precision of the scientific paper, report, article or textbook, popularizations are nevertheless better equipped to communicate the culturally significant aspects of science: the thrill of discovery, the uniqueness and rarity of findings

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[10] John Carey, 'Introduction', in *The Faber Book of Science*, ed. by John Carey (London: Faber and Faber, 1995), pp. xiii–xxvii (p. xiii).

[11] Carey, p. xiv.

[12] Murdo William McRae, 'Introduction: Science in Culture', in *The Literature of Science: Perspectives of Popular Scientific Writing*, ed. by Murdo William McRae (Athens: The University of Georgia Press, 1993), pp. 1–13 (p. 10). Further references to this chapter are given in parenthesis.

and theories, and the meaning of scientific ideas for human life (Cartwright and Baker, p. 302). Hence, rather than associating the attribute *popular* with something that is qualitatively inferior, we would be well advised to see such writing ‘not as mere popular transmission of superior scientific knowledge but as sophisticated production of knowledge in its own right’ (p. 11) — a position that my study wholeheartedly embraces.[13]

At the same time, as much as the aim of popular science writing to tell its stories through strong narratives contributes to the shaping of the cultural value and meaning of science, it has long been evident that the process of signification is by no means restricted to non-fiction, with especially contemporary literature showing a considerable awareness of recent developments in the natural sciences. Excluding the genre of science fiction, which explicitly incorporates scientific ideas into its body, we can observe how notable novelists and dramatists such as Thomas Pynchon, John Fowles, Don DeLillo, Martin Amis, Jeanette Winterson, Richard Powers, Tom Stoppard, and Michael Frayn have either employed scientific ideas as important thematic and structural elements in their work or implicitly responded to questions raised by science.[14] In addition, a more recent yet equally interesting trend is professional scientists’ exploration of the human aspects of science

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[13] Studies on written popular science tend to vary in terms of referring to the actual genre. For instance, while McRae uses *popular scientific writing*, Daniel Cordle simply talks about *science writing* in order to avoid making ‘an easy distinction between low and high culture’ (p. 64). The term used in my study is thus an amalgam of the ones used by critics such as McRae and Cordle, as it wants to avoid a possible confusion between scientific writing and academic writing, and as it preserves the adjective *popular* in order to emphasize the fact that the writing analysed in the discussion is primarily aimed at non-specialists.

[14] See, for instance, *V* (1963), *The Crying of Lot 49* (1966), and *Gravity’s Rainbow* (1973) by Pynchon; *The Magus* (1965, 1977) by Fowles; *White Noise* (1985) by DeLillo; *Time’s Arrow* (1991) by Amis; *Gut Symmetries* (1997) by Winterson; *Hapgood* (1988) and *Arcadia* (1993) by Stoppard; and *Copenhagen* (1998) by Frayn.

through means provided by fiction, as the books of Carl Djerassi and Alan Lightman illustrate.[15]

It is therefore obvious that popular science writing and literature are significant channels through which scientific ideas are disseminated to large audiences today, the former presenting them through entertaining narratives and the latter appropriating and responding to them in various ways. As such, a study that seeks to explore popular science and literature side by side should offer us a comprehensive view of not only how the two cultures interact through writing but also how science is generally perceived in our culture in terms of its human meaning and relevance.

[15] See, for instance, *Cantor's Dilemma* (1989), *The Bourbaki Gambit* (1994), *Menachem's Seed* (1997), and *NO* (1998) by Djerassi; and *Einstein's Dreams* (1993) and *Good Benito* (1995) by Lightman.

1.2 The Aim, Argument, and Relevance of This Study

Given the fact that both popular science writing and literature using or responding to scientific ideas play crucial roles in shaping *cultural science* — a term referring to 'anything that contributes to the general perception — the cultural "value" — of science' (p. 51), as the critic Daniel Cordle aptly puts it — this study aims to examine their means of doing it by answering two interlinked questions: What kinds of means do contemporary popularizers of scientific ideas use in order to convince their audiences of the plausibility of their ideas? How has modern literature responded to ideas in popular science? The third major question explored in my study in turn concerns the cultural meaning of science: How have contemporary popular science writing and modern literature approached topics and concerns shared by both? Since it can be assumed that there are many equally valid ways of dealing with these kinds of questions, I decided to limit my discussion on popular science writing to its rhetorical aspects, since one of the main aims of the genre is to persuade audiences to accept the validity of authors' own viewpoints and theories. The study of the rhetorical aspects of my chosen material mainly focuses on the various figures of speech that can be said to have distinct stylistic and argumentative functions — as I argue throughout my thesis, the two are usually inseparable from each other, with the form determining the content and the content determining the form.[16] This choice is to a considerable extent motivated by the fact that it is through figures of speech such as

[16] This does not mean that I aim to reduce rhetoric to figures of speech; see 1.4 for my reasons for focusing on the figurative language of popular science writing.

metaphor and simile that popularizers seek to introduce new perspectives for viewing scientific issues as well as to state key insights (‘human beings are like particles’, ‘human genes are selfish’, ‘evolution is a branching bush’, ‘the brain is a computer’, for instance). Equally important is the role of figures of speech as epitomes through which the philosophy underlying a particular insight is effectively communicated to readers.

In addition to discussing this aspect of popular science, I analyse how contemporary literature has represented scientific ideas, thus studying the history of scientific ideas in literature. For instance, in chapter 4.2 I examine the implications of the evolutionary biologist Richard Dawkins’s famous selfish gene metaphor by asking whether contemporary fiction agrees with his controversial claim that human behaviour is fundamentally conditioned by the genetic make-up of the individual or whether it suggests that humankind truly possesses free will unaffected by biological determinism. In this way, I show that there are crucial topics and concerns that popular science writing and literature share — identity and knowledge being the most common ones — whose representation is to a considerable extent determined or directed by formal features of language such as those embodied by various figures of speech in popularizations. In chapter 2.2, for instance, I discuss how popular science’s representation of the various paradoxical features of quantum physics reflects the underlying logic of the figure of speech known as synoeciosis, which popularizers use to argue that two seemingly opposite qualities can exist side by side without cancelling each other. I then study how this particular idea communicated through this particular linguistic form resonates with literary characterizations that portray human identity in terms of a fundamental duality, or division, between two clashing qualities of the self.

On the basis on these ideas, I argue that it is possible to identify significant links between the rhetoric of popular science writing and the literary representation of scientific ideas, so that they become two interlinked aspects of cultural science, each continuously shaping our understanding of certain common concerns of science and literature, such as human knowledge and identity.

In addition to defining my aim and argument, I would like to make three points about the relevance of my study. Firstly, it should be noted that the importance of popular science writing as a vast body of texts through which both science and other areas of culture can be assessed is great. Murdo William McRae, for instance, states that '*science must be related to the ideologies, values, habits of thought, and linguistic and rhetorical practices that shape our culture* if we are to understand both its power and its limitations' (p. 1; emphasis original). Hence, it is possible to argue that literary criticism has an important role as a balancing factor in the complex relationship between the natural sciences and the humanities:

> The interface of science with other disciplines has become a matter of urgency in our time, because science is the dominant intellectual discipline, whose authority, influence and, through its practical applications, financial and political power are unequalled. Even on 'ultimate' questions science today has taken the place of both theology and philosophy, and books offering scientific answers to the age-old questions of the formations and the end of the universe, the essential character of human nature and consciousness, and the parameters of decision-making about matters of life and death have attained remarkable popularity.[17]

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[17] Elinor S. Shaffer, 'Introduction: The Third Culture — Negotiating the "two cultures"', in *The Third Culture: Literature and Science*, ed. by Elinor S. Shaffer, European Cultures: Studies in Literature and the Arts, 9 (Berlin: de Gruyter, 1998), pp. 1–12 (pp. 2–3). Further references to this chapter are given in parenthesis.

The methodological tools and knowledge of literary critics should thus enable the critical assessment of the question of how scientific texts build their arguments concerning important topics while attempting to convince audiences of the validity of their claims.

Secondly, and this is linked to the first point, the study of popular science writing is directly relevant to the exploration of questions in genre studies and literary history. This too can be thought of as a task in which the analytical skills of the literary critic are highly productive. 'Popular scientific writing', as Elinor S. Shaffer writes, 'brings into play a range of fictional techniques that the literary analyst may be well placed to recognize' (p. 4).[18] Despite this exciting state of affairs, however, relatively little research has actually been conducted on popular science writing proper.[19] As Jack Selzer observes, although 'there is now general agreement that science is indeed a rhetorical enterprise, specific demonstrations of that contention have been rare',[20] and thus it has been established that 'science writing offers an expansive, generally unexplored, vista for literary and cultural analysis' (Cordle, p. 63). For this reason, critics have in recent years called for studies that

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[18] Envisioning a third culture in which literary scholars play an active role, Shaffer argues that our understanding of the representatives of the third culture should not be restricted to Snow's social historians or Brockman's scientists-cum-popularizers. Instead, she points to those literary theorists who study the interaction of the two cultures on the basis of the assumption that as science exerts influence on literature, it is simultaneously guided by the narrative and rhetorical conventions of literature, thus giving rise to 'a scientific prose' (p. 3).

[19] For studies on popular science writing, see, for instance, McRae's *The Literature of Science*, which focuses on writing targeted at non-specialist, general audiences. Structured around three themes, 'Language and Rhetoric', 'History, Myth, and Narrative', and 'Ideology and Culture', the shared theoretical assumption of the contributors is that science cannot be separated from external factors such as cultural values, ideology, rhetoric, and linguistic practices. Hence, even though the essays approach the popularization of science from a multitude of angles, their theoretical framework is to a considerable extent guided by the position of cultural relativism. In doing so, they stand in opposition to the views of theorists such as Paisley Livingston who argue that science is less affected by the external factors than the relativists claim.

[20] Jack Selzer, 'Introduction', in *Understanding Scientific Prose*, ed. by Jack Selzer, Rhetoric of the Human Sciences (Madison: The University of Wisconsin Press, 1993), pp. 3–19 (p. 6).

focus on how scientific texts use language in practice: ‘We need thoroughgoing and wide-ranging research into the historical and current rhetoric within the sciences […] to gain a grasp of the range of [linguistic] practices [in science]’[21] — a task in which my study directly participates.

Thirdly, and connected to the points made above, the study of scientific texts in juxtaposition with literary texts is valuable from an interdisciplinary viewpoint. For critics such as Cordle, on whose ideas the theoretical framework and methodology of my study is to a considerable extent based, this approach constitutes ‘the most common and the most interesting form that literature-science criticism currently takes, and it is in this form that there is the truest link between the two cultures’ (p. 65). It is through these kinds of studies that we may thus learn to view science and literature as dynamic and interactive rather than static and isolated disciplines — as Patricia Waugh observes, ‘one virtue of studying their relations as an aspect of intellectual history is that it encourages us to recognize the fluidity of their boundaries and relational identities’.[22] As I will show in my discussion, literature and science are engaged in continuous interaction: while literature dramatizes the often unspoken implications of scientific ideas, popular science writing constantly employs specific literary techniques such as the use of figural language and certain narrative structures in order to make those ideas accessible to large audiences. For this reason, studies such as mine may make us more aware of the fact that both fields to some extent

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[21] Charles Bazerman, *Shaping Written Knowledge: The Genre and the Activity of the Experimental Article in Science* (Madison: The University of Wisconsin Press, 1988), p. 332.

[22] Patricia Waugh, ‘Revolutions of the Word: Knowledge’, in *Revolutions of the Word: Intellectual Contexts for the Study of Modern Literature*, ed. by Patricia Waugh (London: Arnold, 1997), pp. 33–55 (p. 38). Further references to this chapter are given in parenthesis.

use devices that ultimately belong to 'the common stuff of human reasoning',[23] therefore emerging from the common ground of language. This realization serves as an important reminder of the notion of the two fields as interlinked products of a shared culture rather than separate domains of thought and activity. Consequently, it may be argued that at the general level of culture, studies exploring scientific and literary texts side by side participate in what Alan G. Gross calls 'the task of reconciliation'[24] between the apparently antagonistic two cultures of the natural sciences and the humanities, as we are encouraged to see the two as interrelated expressions of one underlying culture. The recognition of this fact may help us build and develop an advanced model of culture in which the relationships between its various domains are not needlessly simplified — as in the Snow-Leavis debate's portrayal of the humanities and the natural sciences as each other's antagonists — but studied in terms of their complex, many-levelled interaction.

In the light of these considerations, it should be clear that much can be achieved by the detailed study of popular science writing's use of figurative language and literature's representation of science. Yet, as in all kinds of research, the necessity of limiting the scope of discussion often leads to the feeling that one has to leave out observations that could be relevant from the viewpoint of one's topic. For instance, one possible objection to my way of analysing popular science might be that by focusing on figures of speech, I have neglected other important areas of rhetorical enquiry. Another objection might concern the fact that I hold figurative language as a bridge joining the two fields. Moreover, for a more

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[23] Jeanne Fahnestock, *Rhetorical Figures in Science* (New York: Oxford University Press, 1999), p. 44. Further references to this book are given in parenthesis.

[24] Alan G. Gross, *The Rhetoric of Science* (Cambridge, Mass.: Harvard University Press, 1990), p. 20.

ideologically conscious researcher, my deliberate unwillingness to comment on the ideological, social, or political aspects of cultural science might appear as a reluctance to take a specific stance on such matters. However, while my discussion hopefully invalidates objections such as the second one by showing how figures connect rhetoric and literary representation, its vast scope necessitates the omitting of the analysis of the other areas of rhetoric as well as the analysis of the extratextual dimension. As such, instead of indicating defects in my thesis, the omitted subjects could possibly point to directions in which interested critics might consider heading in future studies.

1.3 The Scope and Overview of the Primary Material

As the scope of my study covers roughly thirty years of popular science writing and literature, I am obliged to offer readers a look of what has been done in the two fields that is perhaps more wide than deep, meaning that my discussion covers a large amount of different kinds of material instead of just focusing on a few key texts in extensive detail. Because both genres offer so many possible critical choices, I decided to focus only on those books that are somehow relevant from the viewpoint of the shared concerns of science and literature. In consequence, while some of my choices in regard to contemporary popular science writing represent well-known classics and best-sellers of the genre such as Fritjof Capra's *The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism* (1975), Richard Dawkins's *The Selfish Gene* (1976), James Gleick's *Chaos: Making a New Science* (1987), Stephen Jay Gould's *Wonderful Life: The Burgess Shale and the Nature of History* (1989), and Joseph Weizenbaum's *Computer Power and Human Reason: From Judgment to Calculation* (1976), others might be less familiar to readers. In the same way, the fictional material contains both major (Ian McEwan's *The Child in Time* (1987), Stoppard's *Arcadia*, and William Gibson's *Neuromancer* (1984), and so forth) and minor works (for instance, Ruth Brandon's *The Uncertainty Principle* (1996), Robert Littell's *The Visiting Professor* (1993), and Daniel Hecht's *The Babel Effect* (2001)). Hence, although my primary material is quite large, it should be made clear that instead of trying to create a canonical paradigm of texts, I have sought to select books that serve an illustrative purpose in terms of my argument while covering a substantial part of the two genres. This in turn means that I am not really concerned with making judgments concerning either the quality of writing or the scientific accuracy of representation, as the only thing that matters in my study is the relevancy of the material for the overall discussion.

The analyses of the primary material have been arranged by four fields of the natural sciences: the so-called new physics of relativity theory and quantum physics, chaos theory and complexity, evolutionary biology, and computer and information technology. In addition to the fact that these fields probably represent the most important areas of inquiry in the natural sciences in the twentieth century, the order in which they are dealt with creates a kind of narrative arc for my discussion. Following the revolutionary insights of the new physics concerning the subatomic world, space, and time, chaos theory has contributed much to our understanding of systems in the macroscopic world. Evolutionary theory, with its direct relevance for defining human identity, in turn serves as a platform for speculations about the future of humankind in the visions of those working on the implications and effects of new technologies in fields such as machine intelligence. Hence, each of these four fields provides a different angle for discussing what it means to be human from the viewpoint of science.

1.4 Theoretical Background and Methodology

Since a notable increase in the number of studies examining the relationship between science and literature in the early 1980s — including classics such as Ronald E. Martin's *American Literature and the Universe of Force* (1981), Michel Serres's *Hermes: Literature, Science, Philosophy* (1982), Gillian Beer's *Darwin's Plots: Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction* (1983), Sally Shuttleworth's *George Eliot and Science: The Make-Believe of a Beginning* (1984), and N. Katherine Hayles's *The Cosmic Web: Scientific Field Models and Literary Strategies in the Twentieth Century* (1984) — many critics and scholars have been engaged in a process of self-interrogation by critically examining their own theories and methodologies. To a considerable extent drawing on the work of the sociologists of science such as Thomas S. Kuhn, Paul Feyerabend, Michel Foucault, François Jacob, Serres, Bruno Latour, and Jean-François Lyotard, they have come to agree on the notion of science as a discourse built on historical and social contingencies and adopted theoretical positions that enable the study of both science and literature with the same methods of textual analysis. For instance, writing in 1987, George Levine suggests that our contemporary understanding of the relationship of the two cultures should be guided by the following three postulates:

> First, that science and literature are two alternative but related expressions of a culture's values, assumptions, and intellectual frameworks; second, that understanding science in its relation to culture and literature requires some understanding not only of its own internal processes, but of the pressures upon it exercised by social, political, aesthetic, psychological, and biographical forces; third, that the idea of "influence" of one upon the

other must work both ways — it is not only science that influences literature, but literature that influences science.[25]

Using the parlance of poststructuralism, Stuart Peterfreund states more explicitly the notion of science as a fundamentally social and textual construction in 1990. According to him, critics of science and literature work

> out of the assumption that, typically, the discourse of literature and science, like any other discourse of a given culture, is language-bound — logocircumferential, not logocentric — and that language itself is the repository of ideological values and critical and methodological praxis, as well as the boundary between the operational ("doing" science or "doing" literature) and the valuative ("discovering" scientific laws and theories "arriving at" literary insights or truths). Within this literature and science seek to confront the indeterminacies that lie beyond, although without any false hope of reducing, let alone totalizing, those indeterminacies.[26]

Because of the textually constructed nature of science, it must follow that the language of science, like that of any other discourse, cannot function as a perfectly transparent window between consciousness and the world. This is David Locke writing in a poststructuralist and constructivist mode in 1992:

> Traditional science […] has a view of the representational character of its discourse that must be challenged. Such representation, I argue, is not, as the traditional view would hold, a verbal image of an external, pre-existent real but rather a conventionalized formulation of a contextualized, conceptualized "real," a re-presentation of a concept, not a representation of a real.[27]

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[25] George Levine, 'Preface', in *One Culture: Essays in Science and Literature*, ed. by George Levine (Madison: The University of Wisconsin Press, 1987), pp. vii–viii (p. vii).

[26] Stuart Peterfreund, 'Introduction', in *Literature and Science: Theory and Practice*, ed. by Stuart Peterfreund (Boston, Mass.: Northeastern University Press, 1990), pp. 3–13 (p. 6).

[27] David Locke, *Science as Writing* (New Haven: Yale University Press, 1992), p. 35.

By suggesting that scientific claims about the world and consequently about truth are texts indicative of various culturally determined social, political, and ideological concerns rather than unproblematic descriptions of how nature really is in itself, this kind of textual constructivism in the late 1980s and early 1990s undermined the notion of science as being able to uncover universal truths through empirical methods (see Cordle, pp. 44–46).

If we accept the idea that science and literature are cultural discourses and hence yield to the methodology of cultural and literary analysis, how should we proceed to construct a model describing their relationship? Somewhat ironically, Levine refers to them as expressions of an underlying one culture, meaning that their languages, or discourses, are different although they often articulate shared concerns.[28] This idea is also evident in Patricia Waugh's discussion in *Revolutions of the Word: Intellectual Contexts for the Study of Modern Literature* (1997) on the common problems encountered by twentieth-century scientists, philosophers, and artists during the epistemological revolution brought about by quantum mechanics: Waugh notes the frustration of luminaries such as Werner Heisenberg, Ludwig Wittgenstein, A. N. Whitehead, Ezra Pound, and T. S. Eliot at the seemingly impossible task of attempting to capture the nature of reality by linguistic means ('Revolutions of the Word', pp. 33–34, p. 36). This shows that contrary to C. P. Snow's claims, the third culture — if understood as a dialogue between science and literature on shared concerns — has in fact existed all along. 'Yet', Waugh writes, 'if we bring imagination and flexibility to the examination of the relations of [Snow's] two cultures, it

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[28] George Levine, 'One Culture: Science and Literature', in *One Culture: Essays in Science and Literature* (see Levine, above), pp. 3–32 (p. 4).

should be evident that communication has been under way for most of the century' ('Revolutions of the Word', p. 38).

Thus, if we acknowledge the existence of problems common for science and literature, we are confronted with the question of how they relate to each other while tackling issues such as language, knowledge, identity, and so forth. Because it focuses on identifying possible connections between two similar-yet-different discourses, science-literature criticism often encounters the problem of establishing them 'without inevitably forging causal links'.[29] Indeed, in her examination of the intellectual context of Virginia Woolf's *To the Lighthouse* (1927), Waugh remarks that in determining the relation of the novel to ideas in other areas of culture in the 1920s,

> our own critical vocabulary seems inadequate: 'influence' seems too strong, 'epistemic' situatedness too weak. The first implies too much intentionality, the latter perhaps not enough. Fancifully, we might imagine the writer, any creative writer, like Gulliver in Lilliput — caught and tied to the ground of culture by numerous, infinitesimal strings, finally breaking loose, and discovering the ties that initially bind may be woven into new and more fantastic tapestries. ('Revolutions of the Word', p. 39)

Waugh's comparison is useful in the sense that it helps us understand better how fiction such as that of Woolf, who in *To the Lighthouse* responds to ideas as diverse as those of the German art historian Wilhelm Worringer, T. E. Hulme, T. S. Eliot, and Ezra Pound, often contains references to ideas at an implicit rather than explicit level. Explaining the same idea, Gillian Beer notes that instead of explicit, 'total' reference, scientific ideas sometimes emerge through 'local' reference of 'the fugitive allusion, the half-understood concept, [and] the evasive reference whose significance takes us only some way' (p. 185). In other

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[29] Gillian Beer, *Open Fields: Science in Cultural Encounter* (Oxford: Clarendon Press, 1996), p. 177. Further references to this book are given in parenthesis.

words, while literature might not contain explicit references to scientific ideas, its language and other formal elements may nevertheless reflect the effect of scientific ideas and theories, indicating that the ideas have become an implicit part of fiction's tapestry (Beer, p. 228).

Instead of thinking in terms of rather self-evident causal links, then, it may be worthwhile to approach the relationship between science and literature through a more flexible model in order not to ignore its complexity. An early, influential example of such a model is the so-called field model of cultural interchange that N. Katherine Hayles uses to describe the relations between interconnected cultural phenomena:

> Perhaps most essential to the field concept is the notion that things are *interconnected.* […]. In marked contrast to the atomistic Newtonian idea of reality […] a field view of reality pictures objects, events, and observer as belonging inextricably to the same field; the disposition of each, in this view, is influenced […] by the disposition of the others.[30]

When science and literature are studied as parts of the same field, emphasis is put on their status as discourses that simultaneously both create and absorb ideas. Accordingly, for Hayles it is the continuous interaction of the things in the field that creates the space of culture as well as the objects located in it. (For this reason it is impossible to observe the field from the outside, because our perception is — to borrow the famous phrase used by Jacques Derrida and others — 'always already' conditioned by it.)[31] Structurally, the field model is vertical (science and literature often influence each other implicitly) rather than

[30] N. Katherine Hayles, *The Cosmic Web: Scientific Field Models and Literary Strategies in the Twentieth Century* (Ithaca: Cornell University Press, 1984), pp. 9–10; emphasis original.

[31] See N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca: Cornell University Press, 1990), pp. xi–xii. Further references to this book are given in parenthesis.

horizontal (science influences literature directly), so that like Levine's idea of one culture, it postulates that literature and science emerge from an underlying cultural matrix.[32]

The concept of a cultural 'field', which Hayles borrowed to the critical parlance of cultural and literary studies from physics, thus implies a revised version of the traditional way of imagining the relationship between the two cultures. In contrast to the simplistic forms of the two cultures model, Hayles's model suggests that causality never functions in a rigid, unidirectional fashion but always within an interconnected field, in which ideas, theories, images, and figures of speech travel in all directions:

> One of the many ideas that the field view revises is the notion of a one-way chain of reaction between the event labeled as the "cause" and that labeled the "effect." […]. I do not mean to imply by this that the literature is "caused" by scientific field models. Rather, the literature is an imaginative response to complexities and ambiguities that are implicit in the models but that are often not explicitly recognized. Thus a comprehensive picture of the field concept is more likely to emerge from the literature and from science viewed together than from either one alone. In this sense the literature is as much an influence on the scientific models as the models are on the literature, for both affect our understanding of what the field concept means in totality.[33]

In order to examine literature and science without simplifying the nature of their relationship, we are invited to understand that links between them are often created in an indirect fashion — an example of this might be, for instance, shared everyday experiences through which scientists and artists are introduced to each other's thought (Hayles, *Chaos Bound*, pp. 4–5). In a culture where the dissemination of information occurs on so massive a scale, such interdisciplinary meetings might take place through shared activities, such as

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[32] See N. Katherine Hayles, 'Information or Noise? Economy of Explanation in Barthes's *S/Z* and Shannon's Information Theory', in *One Culture: Essays in Science and Literature* (see Levine, above), pp. 119–42 (p. 120).

[33] Hayles, *Cosmic Web*, p. 10.

reading books and magazines, watching documentaries, browsing the Internet, going to exhibitions, listening to music, and so forth. Therefore, we do not have to assume that the representatives of one culture necessarily have to be conscious of the ideas of the other one in order to be influenced by them:

> When enough of the implications in these activities point in the same direction, they create a cultural field within which certain questions or concepts become highly charged. Perhaps, for example, Brian Eno might first learn about Roland Barthes through *Time* magazine. Intrigued, he might read one of Barthes's books. Or he might not. The brief article summarizing Barthes's ideas would then become one of the elements in Eno's cultural field, available to be reinforced by other elements until a resonance built up which was strong enough to be a contributing factor in his work. (Hayles, *Chaos Bound*, pp. 4–5)

In this way, Hayles proposes that it is possible to argue that the accumulation of certain powerful, shared cultural experiences between two different areas of culture might account for a conceptual isomorphism between them.

Both the two cultures model of Snow and Leavis as well as Hayles's field model have been developed further by Daniel Cordle in *Postmodern Postures: Literature, Science and the Two Cultures Debate* (1999), a critical work seeking to build a model of the relationship between science and literature that would improve the one abstracted from the two cultures debate by better doing justice to the complexity of their relations. Discussing the implications of the Snow-Leavis debate, Cordle first points out three major flaws in the thinking of the combatants: the two cultures model 'fails to address the vibrant role that science plays in our culture' (pp. 41–42), 'suggests that there is an essential, natural difference between scientific and literary modes of knowledge' (p. 42), and paints a 'stereotypical' (p. 43) picture of science and literature. Having identified the problems, he begins to envision a new and better model by defining the term *culture*. Rather than understanding it in a restricted, value-laden sense as Snow and Leavis did, Cordle, citing the early anthropologist Edward B. Tyler, simply notes that the term refers to '*that complex whole which includes knowledge, belief, art, morals, laws, customs, and any other capabilities and habits acquired by man as a member of society*' (quoted in Cordle, p. 53; emphasis original), a definition that avoids the problematic and simplistic division between the so-called high and low forms of culture in the two cultures debate. He goes on to argue that culture consists of interlinked discourses that like culture, can be given both general and restricted meanings. Generally speaking, then, the term *discourse* can refer to 'a conversation', 'a talk', 'a dissertation' or 'a treatise', 'a lecture' or 'a sermon', or to 'a connected series of utterances; a text'.[34] Cordle, however, uses it in the same sense as contemporary cultural studies do, summarizing its three main functions as follows:

> Firstly, discourse implies a manifestation of power as a consequence of its deployment (perhaps, for instance, as a result of a claim to truth within a particular discourse). Secondly, it operates as a sort of unspoken narrative, a story which is taken to be so fundamental as generally to pass unchallenged when it is invoked by a specific narrative. Thirdly, and importantly, it makes other narratives possible (this is perhaps where its power lies) because it embodies all those assumptions which are fundamental for the working of those narratives. (p. 54)

In contrast to discourse, the term *narrative* refers to a specific text in which the assumptions of discourses are located — 'narrative is what is spoken, and discourse is what remains largely unspoken' (p. 54), as Cordle expresses the distinction between the two. He also notes that their relationship might also be apprehended in the manner of Roland Barthes by examining the relationship between readers and texts:

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[34] *The Oxford English Reference Dictionary*, ed. by Judy Pearsall and Bill Trumble, 2nd edn (Oxford: Oxford University Press, 1996), p. 405.

> Another way of conceiving of the difference between narrative and discourse in a book is to imagine the narrative as a horizontal line which represents the sequence of words the reader encounters in reading the book. The various discourses which underpin that book can then be thought of as a series of vertical lines that intersect the narrative at numerous points, informing the meaning the reader extracts from the book. This meaning will, of course, vary from reader to reader, but it is reasonable to identify certain discourses as culturally favoured, and therefore more likely to be shared by most readers. (p. 55)

Uniting the numerous scientific and fictitious narratives in my study are discourses that typically concern scientific questions with distinct human relevance. For instance, in the first part of my discussion I show how both popular science writing and literature use the new physics as a means of examining shared topics, such as the nature of human identity, knowledge, and the experience of time.

It should be observed that although the above model seems to suggest that these vertical lines run through all types of scientific texts, I am not proposing that all science is culturally determined, as extreme versions of social constructivism do. In order to avoid the problems related to making such claims, Cordle distinguishes between what he calls professional and cultural forms of science. He defines professional science by comparing it to ‘an archipelago of islands slightly apart from the rest (though not a completely separate field as it is in the two cultures model)’ (p. 56), suggesting that it is to some extent culturally determined — although perhaps not so much as social constructivists would have us to believe. Through his comparison Cordle also argues that the relationship between professional science and other cultural areas can be approached from three different angles, depending on how the truth-value of professional science is understood. Viewed from the first angle, science mirrors nature unproblematically and is ‘fed only by the internal logic of the development of ideas’ (Cordle, p. 56), influencing the rest of the culture in a unidirectional fashion through the presentation of its ideas. In contrast, the second angle allows for a multidirectional movement of ‘currents’ between the archipelago of professional science and the rest of the culture, although the flow is still stronger from the former towards the latter, thus acknowledging the idea that the epistemological status of science is partly restricted by political decisions, economy, and ideological factors (Cordle, pp. 56–57). The third angle in turn suggests that professional science is to a considerable extent a social and cultural construct: the flow of these currents is not restricted at all, and it is in fact the other areas of culture that help construct professional science, implying that the truth-value of professional science does not depend on purely objective observation of nature (Cordle, p. 57). (The three angles thus correspond to the three major positions in recent versions of the two cultures debate, such as the Science Wars.)

In whatever way one wishes to define their relationship, the importance of making a clear distinction between professional and cultural science lies in the fact that it can prevent the critic from making claims that are too general in their scope — in other words, it is a way of avoiding intellectual fuzziness. While professional science refers to work done by trained scientists, with whom the public rarely communicates directly, the concept of cultural science points to all the ways in which the scientifically untrained general audiences come into contact with scientific ideas (Cordle, p. 51). From this follows that because as a literary scholar I am not competent to judge the claims of professional science, my study cannot be directly concerned with it. Instead, by focusing my attention on popular science writing and literature, I ensure that I do not step outside my area of expertise, literary criticism.

Like its theoretical basis, the methodology of my study owes much to Cordle's effort of disciplinary self-examination. *Postmodern Postures* is unique in recent science-literature criticism in the sense that it provides a useful way of categorizing different types of research areas available in the field, including topics as diverse as 'The Two Cultures Debate' (p. 61), 'The Influence of Science and Technology on Writers' (p. 62), 'The Representation of Science, Scientists and Technology in Literature', 'Science Writing as a Genre of Literature' (p. 63), 'Shared Metaphors and Discourses' (p. 65), 'The Responses of Literature and Science to Common Topics', and 'Relations Between Literary Theory and Science' (p. 68). While not strictly speaking methodologies as such, these titles refer to seven foci for the critical study of the relationship between science and literature, and Cordle's descriptions of them contain suggestions for possible methods through which they can be profitably approached. (It should be noted that while each of the categories can be studied separately, there exists a considerable overlap between some of them. For instance, while the first and seventh foci represent more or less independent areas of research, the second, third, fourth, fifth, and sixth categories share many concerns.)

My own focus falls on the fourth, fifth, and sixth categories. In the case of the first of these, 'Science Writing as a Genre of Literature', Cordle suggests that while popular science writing can be approached by 'mapping its influences upon, for instance, works of literature', critics could also attempt to 'identify and consider the literary techniques employed in science writing […] or […] to analyse the language in which certain scientific ideas are caged' (p. 65). There are, of course, many roads that could be taken in the analysis of such writing, but, as noted above, for the purpose of accomplishing the aim of my study, I have found it useful to focus mainly on the figurative language of popular science writing, thus engaging in the study of an important aspect of the genre's rhetoric.[35] Inspired by the work of rhetoricians and philosophers and historians of science such as Kenneth Burke, Chaïm Perelman, Thomas S. Kuhn, Michael Polanyi, Jürgen Habermas, Paul Feyerabend, and Stephen Toulmin in the earlier decades, scholars in the 1980s began to pay attention to rhetorical elements in the language of science, consequently producing several important studies.[36] Although approaching scientific texts from a variety of angles, literary and linguistic analyses of rhetoric of science usually focus on three features: style, presentation, and argument.[37] In their study of the history of the scientific article, Alan G. Gross, Joseph E. Harmon, and Michael Reidy define these terms as follows: *style* refers to the syntactical and linguistic features of texts; *presentation* covers the organization and structure of texts and the representation of the data; and *argument* points to the various ways in which the

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[35] To put it briefly, rhetoric of science concerns itself with 'the study of how scientists persuade and dissuade each other and the rest of us about nature, — the study of how scientists argue in the making of knowledge'. Randy Allen Harris, 'Introduction', in *Landmark Essays on Rhetoric of Science: Case Studies*, ed. by Randy Allen Harris, Landmark Essays, 11 (Mahwah: Hermagoras Press, 1997), pp. xi–xlv (p. xii).

[36] Selzer, pp. 5–6; Harris, p. xv. These include, for instance, Bazerman's *Shaping the Written Knowledge: The Genre and Activity of the Experimental Article in Science*, Gross's *The Rhetoric of Science*, Lawrence J. Prelli's *A Rhetoric of Science: Inventing Scientific Discourse* (Columbia: University of South Carolina Press, 1989), Greg Myers's *Writing Biology: Texts in the Social Construction of Scientific Knowledge* (Madison: University of Wisconsin Press, 1990), Locke's *Science as Writing*, Jean Dietz Moss's *Novelties in the Heavens: Rhetoric and Science in the Copernican Controversy* (Chicago: University of Chicago Press, 1993) and *Rhetoric and Dialectic in the Time of Galileo* (Washington, DC: Catholic University of America Press, 2003), Marcello Pera's *The Discourses of Science* (Chicago: University of Chicago Press, 1994), Fahnestock's *Rhetorical Figures in Science*, and Alan G. Gross, Joseph E. Harmon, and Michael Reidy's *Communicating Science: The Scientific Article from the 17th Century to the Present*. Essay collections on this topic include *The Rhetorical Turn: Invention and Persuasion in the Conduct of Inquiry* (Chicago: University of Chicago Press, 1990; edited by Herbert W. Simons), *The Literary Structure of Scientific Argument* (Philadelphia: University of Pennsylvania Press, 1991; edited by Peter Dear), *Persuading Science: The Art of Scientific Rhetoric* (Canton, Mass.: Science History Publications, 1991; edited by Marcello Pera and William R. Shea), *Understanding Scientific Prose*, *Rhetorical Hermeneutics: Invention and Interpretation in the Age of Science* (New York: State University of New York Press, 1997; edited by Alan G. Gross and William M. Keith), and *Landmark Essays on the Rhetoric of Science: Case Studies*.

[37] Alan G. Gross, Joseph E. Harmon, and Michael Reidy, *Communicating Science: The Scientific Article from the 17th Century to the Present* (Oxford: Oxford University Press, 2002), p. 9.

claims are supported in scientific texts.[38] According to this definition, the emphasis of my study is on style, with presentation and argument being discussed insofar as they are directly linked to the first category (figurative language as a stylistic means of persuasively supporting the argument).

A study that I have found particularly useful for the analysis of the figurative language of science is Jeanne Fahnestock's *Rhetorical Figures in Science*. Fahnestock argues that there are certain linguistic structures (figures of speech) in language that through their syntactic form lead into certain kinds of arguments in science. Focusing on the use of figures drawn from classical rhetoric such as antithesis, antimetabole, gradatio, incrementum, and ploche in the history of scientific arguments, she shows how they often epitomize the essences of arguments, their linguistic structures expressing the main content of arguments in rhetorically persuasive forms. (At the level of interdisciplinary relations, this again reminds us of the fact that both the natural sciences and the humanities draw from the common means of verbal expression and cognitive resources — the shared matrix of culture — thus employing certain universal types of human reasoning (Fahnestock, p. viii)). In doing so, figurative language often embodies the whole philosophy underlying the argument, and it is precisely for this reason that its study is so important when we examine the representation of scientific ideas and the shared concerns of science and literature.

In terms of the analysis of rhetoric of science, Fahnestock's monograph is very useful because it expands the scope of the study of figurative language from metaphor to other figures. As Brian Vickers, the author of *In Defence of Rhetoric* (1988), argues, it is

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[38] Gross, Harmon, and Reidy, p. 9.

regrettable that studies of rhetoric have for a long time focused almost exclusively on certain figures while paying little or no attention to others. Vickers notes that the 'progressive atrophy of the discipline'[39] in modern times has its roots in Giambattista Vico's reduction of rhetorical tropes to metaphor, metonymy, synecdoche, and irony. Influenced by Vico's classification of tropes, modern scholars such as Kenneth Burke and Hayden White have worked on the basis on a four-trope system while Roman Jakobson reduced the number even further to two (metaphor and metonymy).[40] Inspired by the efforts of critics such as Fahnestock and Vickers, my study aims to show the wide range of use of rhetorical figures in popular science writing, thus covering the variety of their uses in that particular genre. (It should be noted that rhetoric is not a method in itself. The importance of rhetoric for my study stems from the fact that its vocabulary helps me identify linguistic structures and patterns that have argumentatively significant roles in popular science writing.)

In the case of literature (the fifth and sixth categories), in turn, I follow Cordle's suggestion that the shared topics of science and literature may be approached by 'looking […] for evidence of a linking discourse in the metaphors shared by literature and science writing' (p. 68) — although, as noted, I will modify this by extending the study of figurative language in popular science writing to concern also other important figures — identifying specific scientific ideas and theories in literature, and discussing literature's overall representation of science. In practice, this means that I primarily focus on figurative language, imagery and symbolism, explications of scientific ideas by characters and

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[39] Brian Vickers, *In Defence of Rhetoric* (Oxford: Clarendon Press, 1988), pp. 439–40.

[40] Vickers, pp. 440–42.

narrators, characterization, and narrative structure in order to explore how literary techniques have been used to approach the common concerns of science and literature.

1.5 Structure

My discussion is divided into four main chapters, each of which begins with a brief introduction to the science in question. In general, after introducing central scientific notions in a particular field, I analyse popular science writing and literature by placing the two side by side in order to highlight their various intersections, or shared topics and concerns. Each chapter then ends with a conclusion showing the main implications of the analysis.

Chapter 2 focuses on the new physics, examining how popular science and literature have approach the shared topics of knowledge, identity, and time through the ideas of relativity theory and quantum physics — in other words, I study how science and literature contribute to the creation of the metaphysics of the new physics.

Chapter 3 discusses one of the most influential areas in late twentieth-century science: chaos theory and the study of complex phenomena. In this chapter I analyse how chaos and complexity are made relevant from the human point of view in popular science and literature, focusing on the implications of their ideas on humankind's perception and knowledge of nature.

In chapter 4 I study the popularization and literary representation of evolutionary biology, concentrating on its effect on our understanding of human identity. In order to capture something of the contested nature of the field, I have organized my discussion around two more or less antagonistic theoretical positions: the notion of humans as fundamentally selfish creatures is set against a view that emphasizes our capacity for unselfish behaviour and cooperation. In addition to examining this debate, I discuss how recent representations of evolutionary biology have challenged the Darwinian idea of evolution as gradual change with the notion of sudden, catastrophic change as its true motor.

Finally, chapter 5 explores computer and information technology by examining the relationship between humanity and its computers in the context of the development of artificial intelligence. As in chapter 4 the organization of the subchapters reflects two clashing views in an on-going debate: the idea that computers are capable of becoming intelligent in the same way that humans are intelligent is set against the notion that the human brain and consciousness contain elements that cannot be reduced to computer algorithms.

2. The Metaphysics of the New Physics

Let me begin my discussion on the rhetoric of contemporary popular science writing and the representation of science in literature by considering a field that underwent a veritable revolution during the first half of the twentieth century: physics. Although the paradigm shift from the classical, Newtonian physics to the strange and exciting 'new physics' of relativity and quantum theory was well under way by the 1930s, the large-scale popularization of their essential ideas did not start until much later.[1] Writing in 1983, the physicist Paul Davies observes:

> Over fifty years ago something strange happened in physical science. Bizarre and stunning new ideas about space and time, mind and matter, erupted among the scientific community. Only now are these ideas beginning to reach the general public. Concepts that have intrigued and inspired physicists themselves for two generations are at last gaining the attention of ordinary people, who never suspected that a major revolution in human thought had occurred. The new physics has come of age.[2]

It is difficult to say why there has been such a time-lag between the birth of the revolutionary ideas of modern physics and their introduction to general audiences, and Davies in his best-selling book on the topic, *God and the New Physics* (1983), does not

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[1] Note, however, that some of the early quantum physicists and other scientists did popularize ideas in the new physics prior to and after the Second World War. Well-known examples include, for instance, Sir Arthur Eddington's *The Nature of the Physical World: Gifford Lectures 1927* (Cambridge: Cambridge University Press, 1928), *New Pathways in Science: Messenger Lectures 1934* (Cambridge: Cambridge University Press, 1935), and *The Philosophy of Physical Science: Tarner Lectures 1938* (Cambridge: Cambridge University Press, 1939), Max Born's *The Restless Universe* (New York: Dover Publications, 1951), Heisenberg's *The Physicist's Conception of Nature* and *Physics and Philosophy*, and George Gamow's *The Atom and Its Nucleus* (Englewood Cliffs: Prentice-Hall, 1961) — not to mention the numerous interviews and lectures given by Einstein on the topic of relativity.

[2] Paul Davies, *God and the New Physics* (London: Dent, 1983; New York: Simon & Schuster, 1984), p. vii. Further references to this book are given in parenthesis.

seek reasons for it. What is certain, however, is that the ideas of the new physics truly begun to resonate with the rest of the culture during the socially turbulent late 1960s and early 1970s. 'The fruits of this revolution', Davies goes on, 'are only now starting to be plucked by philosophers and theologians. Many ordinary people, too, searching for a deeper meaning behind their lives, find their beliefs about the world very much in tune with the new physics' (p. vii). In other words, Davies argues that the new physics has become a culturally significant phenomenon because it invites the anchoring of human thought on its authoritative yet flexible conceptual framework that has its basis in nothing less than the fundamental constituents of matter. As my discussion in this chapter shows, contemporary popularizations often seek to address questions about the nature of knowledge, the experience of time, and even human identity through the theories of the new physics, thus attempting to link together the intangible subatomic world and the world of everyday life.

Because of the wide range of applicability of the ideas of the new physics on what are essentially philosophical questions, it comes as no surprise that contemporary popularizations on physics approach the link between science and human life in different ways. While many books discuss philosophical issues related to physics, they generally avoid making definite conclusions about them, thus presenting the links between science and philosophy as speculative possibilities rather than established truths.[3] In contrast, other books deliberately cross the line between science and philosophy, often seeking to offer their readers metaphysical systems based on the theories of modern physics.[4] My analyses

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[3] This is the approach taken, for instance, by Davies's *God and the New Physics* and the science writer John Gribbin's *In Search of Schrödinger's Cat: Quantum Physics and Reality* (Toronto: Bantam Books, 1984).

[4] This category includes books that usually link the new physics to what is distinctively New Age thought. See, for instance, Fred Alan Wolf's *Taking the Quantum Leap: The New Physics for Nonscientists* (New

below contain examples of both kinds of approaches: while the books discussed in 2.2, Fritjof Capra's *The Tao of Physics*, Gary Zukav's *The Dancing Wu Li Masters: An Overview of the New Physics* (1979), and Danah Zohar's *The Quantum Self* (1990), are mainly concerned with articulating a metaphysics based on the insights of the new physics and various philosophies, Davies's *God and the New Physics* (1983) and *About Time: Einstein's Unfinished Revolution* (1995), analysed in 2.3, prefer a more conservative approach.

The narrative fiction and drama examined alongside the popular science, Jeanette Winterson's *Gut Symmetries*, Ruth Brandon's *The Uncertainty Principle*, Tom Stoppard's *Hapgood*, Michael Frayn's *Copenhagen*, and Ian McEwan's *The Child in Time*, illustrate the various ways in which written art has responded to the ideas of the new physics and in so doing points to three major topics shared by science and literature: identity, knowledge, and time. As in the other analytical chapters, then, my focus is on how popular science writing and literature together participate in the creation of cultural science by approaching common concerns.

Before going into the actual analyses, however, let us take a brief look at the history and philosophical implications of the new physics in order to establish a proper context for the discussion.

York: Harper & Row, 1982), *Star Wave: Mind, Consciousness, and Quantum Physics* (New York: Macmillan, 1984), *The Body Quantum: The New Physics of Body, Mind, and Health* (New York: Macmillan, 1986), and *The Spiritual Universe: One Physicist's Vision of Spirit, Soul, Matter, and Self* (New York: Simon & Schuster, 1996).

2.1 From Classical Physics to the New Physics

The paradigm shift from Newton's classical physics to the new physics of relativity theory and quantum physics was famously initiated by Einstein's formulation of the special theory of relativity, which, as the physicist Heinz Pagels notes, 'changed forever the way we think about space and time'.[5] Einstein's crucial insight in his 1905 paper was that all our measurements of space and time are relative to our movement, which effectively demolished the Newtonian notion of the universality and independency of these concepts.[6] Ten years later Einstein formulated his general theory of relativity by extending the ideas of the special theory to the phenomena of accelerated motion and gravitation, envisioning gravity as a curvature of the space-time continuum. He predicted that light curves as it travels in the four-dimensional field of space, replacing Newton's idea that gravitation occurs because of a force between bodies of matter with the idea that matter affects the geometry of space surrounding it.

The early years of the twentieth century also saw the development of quantum theory, which became the basis of the second revolution in modern physics. Quantum theory originated with the German theoretical physicist Max Planck, who in 1900 presented a theory according to which atoms and molecules emit energy in fixed amounts, or quanta. Planck's hypothesis led Einstein to suggest that forms of electromagnetic radiation such as

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[5] Heinz R. Pagels, *The Cosmic Code: Quantum Physics and the Language of Nature* (New York: Simon & Schuster, 1982), p. 16.

[6] See Paul Davies, *About Time: Einstein's Unfinished Revolution* (London: Penguin, 1995), pp. 47–49. Further references to this book are given in parenthesis.

light can be thought of consisting of particles and to consequently propose an alternative to the earlier description of light as a wave-like pattern. The next crucial moment in the history of quantum theory came in 1913, when the Danish theoretical physicist Niels Bohr proposed that electrons orbiting the nuclei of atoms correspond to particular amounts of energy, thus creating a new model of the atom. In 1924 Louis-Victor de Broglie in turn attempted to expand these insights by hypothesizing that just as light waves exhibit particle-like behaviour, particles such as electrons could behave like waves.

In the minds of physicists such as Erwin Schrödinger, Werner Heisenberg, Max Born, Wolfgang Pauli, and Paul Dirac, these early visions developed into a theory of atomic structure called quantum mechanics during the latter half of the 1920s. Schrödinger suggested that instead of being particles, electrons are material waves, thus giving birth to the so-called wave mechanics that enabled him to describe subatomic phenomena mathematically — a Schrödinger equation is a differential equation for the wave function of a particle that can be used to describe everything in observable physical reality. Heisenberg, Born, Pauli, and Dirac in turn formulated the so-called matrix mechanics, which they used to create a purely mathematical atomic theory. Although the theories of Schrödinger and Heisenberg were incompatible in respect to each other — the former described the behaviour of electrons as continuous waves while the latter saw it as discontinuous and non-localizable — it became evident that their equations gave precisely the same predictive results, consequently establishing the mathematical basis of quantum mechanics. From the viewpoint of the philosophical implications of the new physics, it is important to observe that as they describe the behaviour of subatomic particles statistically, these theories deal with knowledge that is probable rather than certain. From this state of affairs follows that because we cannot precisely describe the motion of subatomic particles, our knowledge of the world is bound to be incomplete.

The suggestion that reality cannot be described in its totality is perhaps most evident in Heisenberg's famous uncertainty principle, which the German mathematical physicist and philosopher formulated in 1927. The uncertainty principle — or the principle of indeterminacy, as it is sometimes called — can be summarized as follows: It is impossible to measure precisely certain pairs of physical properties at the same time, such as the momentum and position of subatomic particles (these properties are uncertain in the sense that instead of existing as definite values, they are events within a range of probability). The fact that we can measure only one property at a time suggests 'that there are limits on what is *measurable* and [that] it is impossible to do anything other than speculate on what is not measurable'.[7] In other words, our measurement of subatomic particles always gives us only one half of the story while the other half remains hidden.

In addition to the view of knowledge, the uncertainty principle has important implications for our understanding of causality and the linguistic description of physical reality. Because scientists cannot rely on precise measurement when observing quantum phenomena, they cannot make accurate predictions concerning the behaviour of particles. In contrast to the causal clarity of the Newtonian universe in which events follow neatly from prior events, the fundamental level of matter as described by quantum physics appears to be quite ephemeral: whereas classical physics assumes that the basic laws of nature are differential equations describing the incremental, continuous change of the coordinates of

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[7] Jim Baggott, *The Meaning of Quantum Theory* (Oxford: Oxford University Press, 1992), pp. 32–33; emphasis original.

time and space, quantum physics maintains that these changes are discontinuous in the sense that they entail a series of finite steps that do not allow for an exact description. Consequently, it is impossible to describe physical reality in an entirely deterministic fashion, as such descriptions would be incompatible with our observations of reality. Because it is impossible to make precise predictions about the behaviour of particles, quantum physics suggests that at its most fundamental level, matter cannot be represented accurately. Accordingly, although it is possible to model reality, we are forced to admit that it might be impossible to describe things as they really are in themselves. 'What we observe is not nature itself,' Heisenberg notes, 'but nature exposed to our method of questioning.'[8] This means that 'there is no deep reality for us to discover in the traditional sense, only a description of it'.[9]

In addition to implying that 'physical events [are] forever unknowable and unpredictable',[10] quantum theory made certain counterintuitive statements about reality. For instance, Born's interpretation of Schrödinger's wave functions proposes that matter has a paradoxical dual nature, as it can simultaneously display particle-like and wave-like qualities. This realization led Niels Bohr to formulate his principle of complementarity in 1927 as a means of accounting for the paradox. In the so-called Copenhagen interpretation of quantum theory — of which the uncertainty principle forms a crucial part — Bohr suggests a view of reality that regards the qualities of particles (speed and location, for

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[8] Werner Heisenberg, *Physics and Philosophy: The Revolution in Modern Science*, ed. by Ruth Nanda Anshen (New York: Harper, 1958), p. 58.

[9] John D. Barrow, *The World Within the World* (Oxford: Oxford University Press, 1988), p. 150.

[10] Pagels, p. 65.

instance) as complementary features of reality, indicating that the qualities are meaningful only when compared to each other.[11]

The importance of complementarity for the philosophy of quantum physics is evident not only in what it says about matter but also in what it suggests about the relationship of humankind and nature. Because it is impossible to make observations of physical reality without interacting with the observed phenomena (using a particle such as a photon to bombard another particle in order to measure one quality inevitably alters the value of its complementary quality), observers are always inseparable from the systems they observe. As Heisenberg puts it, 'Science no longer confronts nature as an objective observer, but sees itself as actor in this interplay between man and nature.'[12] Bohr too recognized this. 'An independent reality in the ordinary physical sense', he writes, 'can neither be ascribed to the phenomena nor to the agencies of observation.'[13] Hence, when scientists measure the behaviour of particles, the measuring instruments themselves always affect the outcome of the experiment, and the observers cease to be neutral agents, as they must make the decision to focus on one quality at the expense of the other.

On the basis of points such as the ones made above, it has been suggested that the discoveries of quantum physics question some of the fundamental assumptions of Western philosophy. For instance, cultural critics Steven Best and Douglas Kellner observe that the Aristotelian either-or logic may not appear as a valid way of describing reality if it is taken

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[11] Baggott, pp. 85–86.

[12] Werner Heisenberg, *The Physicist's Conception of Nature*, trans. by Arnold J. Pomerans (New York: Harcourt, 1958), p. 29.

[13] Niels Bohr, *Atomic Theory and the Description of Nature* (Cambridge: Cambridge University Press, 1934), p. 54.

for granted that what we see is determined not only by what we want to see (the scientist chooses to focus on one half of a complementary pair of qualities) but also by the devices used for making observations.[14] Light, as noted, exhibits the properties of both waves and particles, and it is not until we decide which aspect we want to focus on that it appears as one of the two (Best and Kellner, *The Postmodern Turn*, p. 216). Because complementarity thus suggests the logic of both/and rather than either/or, Best and Kellner note that the philosophy of quantum physics implies that no single interpretation does full justice to the world's complexity, taking us further away from modern monoperspectivism towards postmodern multiperspectivism (*The Postmodern Turn*, pp. 216, 225).

In contrast to the revolutions of the early decades of the twentieth century, it seems to be unclear whether or not the future of physics will have further intellectual upheavals. While many scientists working in the field of superstring theory, a theory that seeks to unite relativity and quantum physics into a so-called theory of everything, appear to be optimistic about the ability of physics to make significant discoveries about reality, others feel that physics is unlikely to achieve them. As one of the scientists interviewed by the science writer John Horgan for the book *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age*[15] (1996) puts it, the 'truth is, there is nothing — there is *nothing* — of the same order of magnitude as the accomplishments of the invention of

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[14] Steven Best and Douglas Kellner, *The Postmodern Turn*, Critical Perspectives (New York: Guilford Press, 1997), p. 215. Further references to this book are given in parenthesis.

[15] As regards its argument, Horgan's book is rather controversial: through individual portraits of famous scientists such as Lynn Margulis, Roger Penrose, Richard Dawkins, Murray Gell-Mann, Stephen Jay Gould, and others, Horgan argues that contemporary science is characterized by a deep-seated sense of exhaustion, as the future does not appear to promise any major intellectual breakthroughs.

quantum mechanics or of the double helix or of relativity'.[16] For Horgan, such pronouncements show that the efforts of today's physics are ultimately ironic: exceedingly speculative and abstract, the claims of those working on theories of everything are currently impossible to prove empirically (p. 62). (For instance, a hypothetical particle accelerator that could provide physicists with information about the environment of the infinitesimally tiny strings (superstrings) would have to be of astronomical proportions (Horgan, p. 62).)

Whatever the future of contemporary physics may bring, it is clear that the ideas of the new physics have had a deep impact on our understanding of the external reality and, as the following analyses show, they have also provided our culture a conceptual means of understanding both ourselves and our relationship with the world. Below I first discuss how contemporary popular science writing and literature have approached questions concerning identity and knowledge through the new physics. I then conclude my discussion by considering yet another shared topic: time.

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[16] Quoted in John Horgan, *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* (Boston, Mass.: Addison-Wesley, 1996; London: Little, 1997), p. 28. Further references to this book are given in parenthesis.

2.2 *The Physics of Knowledge and Identity*

Although the philosophical implications of the discoveries of the new physics continued to occupy the minds of the field's seminal figures such as Niels Bohr and Werner Heisenberg, it was not until the middle of the 1970s that there emerged the tendency to explicitly link the science of the microscopic to the world of human affairs.[17] While many professional scientists have been rather cautious in establishing analogies between the two, those responsible for the popularization of the new physics in the last thirty years have often gone in the opposite direction. For instance, best-selling writers such as Fritjof Capra, Gary Zukav, Ken Wilber, and Fred Alan Wolf have sought in quantum physics solutions to various issues in human life: the relationship of science and religion, the mind-body problem, the nature of consciousness, individual development, and social issues appear as recurrent themes in their writing. At times strongly flavoured by New Age thinking, such writing habitually seeks to find confirmation for the validity of various mystical and holistic ideas in the authoritative theories of what has been considered the most fundamental of the natural sciences.

Regardless of how one may feel about the acceptability of making a metaphorical link between the microscopic and the macroscopic,[18] it should be acknowledged that the

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[17] For discussions by Bohr and Heisenberg on the philosophical side of quantum physics, see, for instance, the former's *The Unity of Knowledge* (New York: Doubleday, 1955) and *Atomic Physics and Human Knowledge* (New York: John Wiley, 1958), and the latter's *Physics and Philosophy*.

[18] For instance, the cognitive scientist and author Douglas R. Hofstadter claims that much of the philosophical confusion around ideas such as the uncertainty principle stems from careless analogies drawn between the subatomic world and the world of human affairs. Douglas R. Hofstadter, 'Heisenberg's Uncertainty Principle and the Many-Worlds Interpretation of Quantum Mechanics', in *Metamagical Themas: Questing for the*

phenomenon became so widespread in the popularization of the new physics in the 1970s and 1980s that dismissing it altogether would leave our discussion of the cultural meanings of science incomplete. Hence, the analyses below seek neither to question nor affirm the validity of the authors' claims but to examine the link between their rhetoric and the portrayal of ideas derived from the new physics in narrative fiction and drama.

2.2.1 Drawing the Analogy between the Microscopic and the Macroscopic

I begin my analysis by discussing the first — and probably the best-known — popularization on the new physics that explicitly links the science to a certain philosophy: the Austrian-born physicist Fritjof Capra's *The Tao of Physics*. Published in 1975, this seminal precursor to a whole subgenre of similar books attempts to build a bridge between the worldviews of modern physics and, mainly, Eastern philosophies. Using a tripartite structure (the first part offers a brief history of twentieth-century physics and a discussion on the problems of description in quantum physics; the second part features an introduction to the doctrines of the various schools — Hinduism, Buddhism, Chinese philosophy, Taoism, and Zen — of Eastern mysticism; and the third part draws the actual parallels

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Essence of Mind and Pattern (New York: Basic Books, 1985), pp. 455–77 (pp. 455–57). Noting that Heisenberg's mathematical formulation of uncertainty does not state that there is an observer that somehow affects the observed, Hofstadter writes that 'it is a total misinterpretation of Heisenberg's uncertainty principle to suppose that it applies to macroscopic observers making macroscopic measurements'. Hofstadter, pp. 463–64.

between Western science and Eastern thought), Capra's bases his argument on numerous analogies that he draws between the discoveries of the new physics and various systems of thought. 'The parallels to modern physics', he claims in the introduction to his book, 'appear not only the *Vedas* of Hinduism, in the *I Ching*, or in the Buddhist *sutras*, but also in the fragments of Heraclitus, in the Sufism of Ibn Arabi, or in the teachings of the Yaqui sorcerer Don Juan.'[19] In this way, Capra argues that in spite of their different ways of expressing things, the new physics and mysticism converge through their remarkably similar descriptions of the world, with the former providing tangible scientific evidence for the claims of the latter. For Capra, the building of such a conceptual bridge is also a means of 'improving the image of science' (p. 12), as the incorporation of Eastern views into science could in his opinion introduce a measure of spirituality to its technological applications.

The Tao of Physics begins by directing its readers' attention to a specific philosophical problem for which it proposes a solution through scientific insight. Capra notes that individuals living in modern society suffer from 'inner fragmentation' (p. 9) caused by the Cartesian division of mind and body. This split is in turn reflected in the way in which humankind experiences the world: instead of forming interconnected wholes, objects and phenomena are viewed as if they existed in strict separation from each other (p. 9). This state of affairs in the human psyche, Capra argues, has led to a 'series of social, ecological, and cultural crises' (p. 9) that manifest themselves as alienation from both nature and other individuals, economic and political imbalance, violence, pollution, and other similar

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[19] Fritjof Capra, *The Tao of Physics: An Exploration of the Parallels between Modern Physics and Eastern Mysticism* (Boulder: Shambhala, 1975; London: Bantam, 1977), p. 5. Further references to this book are given in parenthesis.

problems. In order to propose an alternative to the considerably mechanistic worldview of Cartesianism, Capra suggests that we adopt the worldview of Eastern thought, which is characterized by an emphasis on the organic unity of things: instead of postulating the existence of atomistic and static individual units, Eastern philosophies conceive the world in terms of relationships that constitute a unified fundamental reality (p. 10). In this respect, then, there are two main themes in Eastern thought that Capra wishes to integrate into the worldview of Western thought: 'the unity and interrelation of all phenomena and the intrinsically dynamic nature of the universe' (p. 11).

Accordingly, the primary metaphor of the book portrays the world as an interconnected web. 'The most important characteristic of the Eastern world', Capra notes, 'is the awareness of the unity and mutual interrelation of all things and events, the experience of all phenomena in the world as manifestations of a basic oneness' (pp. 116–17). In order to illustrate the idea that all binary opposites — phenomena ordinarily perceived as separate — form unities, he uses the rhetorical strategy of linking the opposite terms through a figure of speech known in classical rhetoric as synoeciosis, the bringing together of contraries in order to show their essential oneness.[20] As mystics transcend the world of duality, Capra observes, they realize 'that good and bad, pleasure and pain, life and death, are not absolute experiences belonging to different categories, but are merely two sides of the same reality; extreme parts of a single whole' (p. 130). In the same manner, he notes how the 'notion that all opposites are polar — that light and dark, winning and losing, good

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[20] The definitions of the various rhetorical terms used in my study mainly derive from Jeanne Fahnestock's *Rhetorical Figures in Science* and Brian Vickers's *In Defence of Rhetoric*. When the definitions are so general that they can be regarded as universally accepted statements concerning the meanings of the terms, I have omitted references. In addition to printed sources, the interested reader will find related terminology and definitions on the Internet (see, for instance, *Silva Rhetoricæ* at http://humanities.byu.edu/rhetoric/silva.htm).

and evil, are merely different aspects of the same phenomenon — is one of the basic principles of the Eastern way of life' (p. 131). This idea is also conveyed by Capra's quotation of a Zen poem, which, characteristically of Zen thought, expresses a paradox through the linguistic means of bringing together two seemingly contradictory images: 'At dusk the cock announces dawn; | At midnight, the bright sun' (quoted in Capra, p. 131). Noting that such insights are by no means limited to Eastern philosophies, Capra also quotes the Greek philosopher Heraclitus, who apparently viewed the universe in terms of constantly changing polar opposites: 'God is day night, winter summer, war peace, satiety hunger' (quoted in Capra, p. 104). In other words, the opposites are joined together through linguistic structures that juxtapose two seemingly contradictory terms in order to emphasize oneness rather than difference. (Note that in the last example the pairing of the opposites is done in a way more characteristic of oxymoron than synoeciosis, as the terms are placed adjacent to one another.)

The idea of polar opposites forming complementary pairs is also found in the familiar visual image of male-female (yang-yin) polarity, which features the circle of Tao divided into wave-shaped halves, each containing a small circle against the background of the other half's colour. Rhetorically speaking, this image, which appears as an illustration both on the cover and in the pages of *The Tao of Physics*, can be thought of as a visual antimetabole, a figure that in its linguistic form repeats two words in successive clauses while reversing their grammatical order: rotationally symmetrical, the yang half contains the 'seed' of yin while the yin half contains the 'seed' of yang.[21] In Capra's argument the sense of symmetry

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[21] In her study of rhetorical figures in science Fahnestock defines antimetabole as an inverted 'bicolon' (p. 123), in which not less than two terms from the first colon must be transported to the second one in order for the bicolon to qualify as an antimetabole. Although it is hence structurally similar to another figure of

characteristic of antimetabole in this way supports the notion of intuition and rationality as approaches to knowledge that instead of being opposed complement each other. Suggesting that the two are interrelated concepts through its form, the antimetabole in the circle of Tao thus has the distinctive function of conveying a sense of completeness and balance, as it links together two terms that for Capra have often been seen as diametrical opposites in the history of Western thought.

Moreover, the sense of symmetry associated with this figure foregrounds the idea that relationships between complementary pairs are dynamic rather than static. As one of the polar forces rotates to its limit, the other one begins a similar motion because the former already contains the seed of the latter. In the chapter on Chinese thought, for instance, Capra cites *Tao-te-Ching*[22] as follows: 'The *yang* having reached its climax retreats in favor of the *yin*; the *yin* having reached its climax retreats in the favor of the *yang*' (quoted in Capra, p. 96; emphases original). This passage gives the visual antimetabole a verbal form, with the reversal of the main terms conveying a sense of dynamic interplay between the two forces. The same idea is evident in a passage quoted by Capra from the Taoist mystic and prose writer Chuang-tzu, a student of the famous Lao-tzu:[23]

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conceptual reversal, chiasmus, which for Fahnestock is 'a variant of the antimetabole' (p. 123), textbook antimetaboles preserve the exact form of the reversed words. In contrast, in chiasmus a word in the first colon is often replaced by a synonym, a word of an opposite meaning, or a word belonging to the same conceptual category in the second, as in 'Napoleon was defeated by a Russian winter and the snows of Leningrad destroyed Hitler' (quoted in Fahnestock, p. 123). Because of the reversed repetition of the key terms, antimetaboles are usually not only easy to identify but also easy to memorize. For instance, in the history of political speeches, the suggestion 'Ask not what your country can do for you; ask what you can do for your country' (quoted in Fahnestock, p. 123) from John F. Kennedy's inauguration speech in 1961 is probably one of the most memorable examples of this figure.

[22] Written around the fourth and third centuries BCE, *Tao-Te-Ching* is the central Taoist text, defining the concept of Tao and the philosophy of Taoism.

[23] Lao-tzu is the mythical founder is Taoism to whom *Tao-te-Ching* is ascribed.

> The “this” is also “that.” The “that” is also “this.” […] That the “that” and the “this” cease to be opposites is the very essence of *Tao*. Only this essence, an axis as it were, is the center of the circle responding to the endless changes. (quoted in Capra, p. 102; emphasis original)

As in the previous quotation, the reversal of the main terms establishes a sense of balance and completeness: the opposites *this* and *that* form a complementary, dynamic relationship with each other, which ceases to exist when the Taoist mystic supposedly perceives reality directly by transgressing the illusory world of binary opposites.

The notion of everything as a part of an interconnected web is present also in Capra’s discussion on how modern physics has come to redefine some of the important concepts of classical physics. For instance, he notes that classical physics made a clear distinction between matter and empty space, but general relativity, however, showed that the two are inseparable, as ‘matter cannot be separated from its field of gravity, and the field of gravity cannot be separated from the curved space’ (p. 194). Note how Capra again uses antimetabole’s characteristic reversal of the main terms in order to foreground their interdependent relationship, arguing that Einstein’s theory connected what were considered separate concepts in the atomistic visions of Democritus and Newton. Instead of particles existing as separate building blocks of matter, then, they are now viewed as part of a quantum field, which, Capra argues, corresponds to the concept of ‘the Void’ in Eastern mysticism: ‘The phenomenal manifestations of the mystical Void, like the subatomic particles, are not static and permanent, but dynamic and transitory, coming into being and vanishing in one ceaseless dance of movement and energy’ (p. 198). In this passage Capra first employs antithesis to separate the views of classical physics and quantum physics on matter from each other.[24] After having established the difference, he proceeds to use synoeciosis (*coming into being and vanishing*) in order to describe the dynamic nature of the quantum field: instead of Newton's universe of indestructible, solid particles moving through a void, we are offered the image of the quantum field as a metaphoric dance of energy in which particles are constantly created and destroyed. Moreover, in order to describe the dance of the particles linguistically, Capra juxtaposes the above antithesis with a quotation from the *Upanishads*[25] as follows: 'Tranquil, let one worship [the Void] | As that from which he came forth, | As that into which he will be dissolved, | As that in which he breathes' (quoted in Capra, p. 198). The anaphora in this poetic description emphasizes the notion of life as a ceaseless cycle of birth and death that Capra compares to the dynamic nature of the all-pervasive quantum field, uniting the microcosm of the individual consciousness to the macrocosm of the universe.

The concepts of the quantum field and the Void provide Capra a means of giving an answer to 'the old question whether matter consists of indivisible atoms or of an underlying continuum' (p. 201). 'The field', he writes, 'is a continuum which is present everywhere in space and yet in its particle aspect has a discontinuous, "granular" structure' (p. 201).

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[24] The syntax of antithetical constructions favours a parallel structure, which makes them both visually and aurally recognisable (Fahnestock, pp. 49–50). (Note, however, that antitheses may also be constructed through structures that do not employ parallelism.) Jeanne Fahnestock notes that in most cases, writers derive antitheses from three sources: the terms may be contrary (clean/dirty), contradictory (clean/unclean), or correlative (teacher/student) in relation to each other (pp. 47–49). Although audiences can be expected to be familiar with certain culturally well-established antitheses (human/machine, male/female, and so forth), writers may for argumentative purposes deliberately introduce antitheses that go against these expectations. Moreover, antitheses are often used to reconfigure oppositions that already exist as conceptual oppositions or contrasts, but although such operations do not make the antithesis disappear, they nevertheless change or reconfigure it (Fahnestock, p. 58).

[25] The name *Upanishad* refers to each of a series of Hindu sacred writings that are based on the Vedas, written around 800–200 BCE.

Hence, as in many arguments that seek to unify two opposing ideas, Capra introduces a pre-existing third term that encompasses both: when understood in terms of the quantum field or the Void, the two views on the composition of matter are shown to be complementary rather than contradictory.[26] After placing them under the third term, Capra proceeds to draw an analogy between 'a similar dynamic unity between the Void and the forms which it creates' (p. 201). In order to underline the notion that opposite concepts are always complementary aspects of an underlying whole, Capra cites a Buddhist Sutra as follows: 'Form is emptiness, and emptiness is indeed form. Emptiness is not different from form; form is not different from emptiness. What is form that is emptiness; what is emptiness that is form' (quoted in Capra, pp. 201–02). Through the Sutra's three consecutive antimetaboles, Capra foregrounds the idea that form and emptiness, matter and empty space, are not — as common sense would have it — mutually exclusive opposites but interrelated expressions of the same reality.

Consequently, because the universe allegedly is an interconnected web in which particles dance their endless dance, Capra argues the new physics forces us to view everything around us in terms of relationships rather than individual units, since we cannot talk about 'elementary particles or fundamental fields' (p. 275) anymore. Instead of reducing the world to basic units as atomism does, then, Capra suggests that Western thought adopt a worldview based on the web metaphor:

> In the new world-view, the universe is seen as a dynamic web of interrelated events. None of the properties of any part of this web is fundamental; they all follow from the properties

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[26] Using such a term is basically a means of undoing or challenging an established antithesis, as it gives the opposing terms a common predicate (X and Y are both parts of Z) (Fahnestock, p. 88).

of the other parts, and the overall consistency of their mutual interrelations determines the structure of the entire web. (p. 276)

Having delineated his vision in these terms, he proceeds to draw yet another comparison between the new physics and Eastern philosophies by finding a parallel idea in Taoism for the dynamic model of Western science. In order to illustrate the notion of the universe as a web of self-consistent, interrelated phenomena, Capra again cites *Tao-te-Ching*: 'Man follows the laws of earth; | Earth follows the laws of heaven; | Heaven follows the laws of *Tao*; | *Tao* follows the laws of its intrinsic nature' (quoted in Capra, p. 279; emphases original). The passage's rhetorical effectiveness in the context of Capra's argument stems from the fact that it uses repetition to form a series of causally linked items. More specifically, the passage employs gradatio — or climax, as the figure is also known as — a series of clauses or sentences, each of which repeats the end of the previous clause or sentence.[27] The ascending gradatio points to the idea that as a web of relations, the universe cannot be reduced to things such as fundamental particles because the particles themselves exist only in relation to other particles. In the totality of Tao, the underlying principle of the universe, then, the parts of the universe do not emerge from fundamental laws but function according to their intrinsic nature within a hierarchy of wholes, all parts being equal and linked to each other, as the repetition of the items in the series aims to show. Moreover, Capra quotes the yogi Sri Aurobindo in order to illustrate the notion of how interdependent parts form a hierarchical whole: 'Nothing to the supramental sense is really finite; it is founded on a feeling of all in each and of each in all' (quoted in Capra, p. 282) — the

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[27] In this sense, gradatio is a figure that combines the formal characteristics of incrementum, a figure that lists items according to the order of their importance, and anadiplosis, a figure of repetition that repeats the ending of a structure at the beginning of the next (Fahnestock, pp. 93–94).

passage uses antimetabole as a linguistic means of epitomizing the underlying holistic philosophy.

In addition to the web metaphor, Capra finds a parallel to the idea expressed by the above gradatio in Leibniz's monadology: like the interrelated web of Taoism, a monad can be pictured as a self-contained unit of being that forms relationships with other similar entities. He begins his discussion of this parallel by quoting the English translation of *Lehrsätze über die Monadologie* (1720) as follows:

> Each portion of matter may be conceived of as a garden full of plants, and as a pond full of fishes. But each branch of the plant, each member of the animal, each drop of its humors, is also such a garden or such a pond. (quoted in Capra, pp. 288–89)

The rhetorical force of this passage stems from Leibniz's use of a figure of repetition called ploche, the syntactically free repetition of the same word or phrase. This simple figure that repeats the adjective *each* places emphasis on the idea presented in Sri Aurobindo's antimetabole: the part and the whole are reflections of each other and form the totality of the world. Linking different concepts together, the ploche amplifies the sense of everything being a part of an interconnected web of relations, supporting Capra's argument about the similarity of the ways in which philosophy and the new physics describe the relationship between the part and the whole. 'If the poet', he writes, alluding to the Romantic vision of William Blake, 'sees the world in a grain of sand, the modern physicist sees the world in a hadron' (p. 288).

In fact, it is to a considerable extent this kind of model on which the new vision in *The Tao of Physics* is based. While confessing that its implications are purely speculative at the moment, Capra expresses his belief that the theory will eventually become a '*vision* of nature' (p. 292; emphasis original) that goes beyond the range of human intellect and language, thus becoming what he calls complete knowledge (p. 292). In order to epitomize his argument, he cites Lao-tzu as follows: 'He who knows does not speak, | He who speaks does not know' (quoted in Capra, p. 292). In this passage antimetabole is used to distinguish between two types of knowledge: the complete knowledge that is essentially incommunicable and the incomplete knowledge conveyed by human sign systems. Hence, the status Capra grants to a future version of the new physics is similar to that of mystical knowledge that exists beyond the limits of human reason.

At the end of *The Tao of Physics*, the problem of knowledge emerges as a shared problem for the mystic and the scientist. For Capra, the fact that both mysticism and science verbally interpret their observations makes knowledge based on the use of language incomplete by default. He finds an apt description of this situation in Einstein's aphorism that makes a comment on the limits of mathematical knowledge: 'As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality' (quoted in Capra, p. 27). That Einstein's antimetabole contains two negations suggests a strong denial of the possibility that mathematics could ever directly represent reality. Human knowledge is always bound to be approximate, since scientific models and verbal descriptions of mystical experiences can describe them only in an indirect way, capturing just a part of their essential reality. Complete knowledge, in contrast, is by default inaccessible by language and conceptual thought because access to it requires an unmediated contact with reality. 'The problem of language encountered by the Eastern mystic', he notes, 'is exactly the same as the problem the modern physicist faces' (p. 33). As we have seen above, the problem of describing the world is especially evident in the case of the various paradoxes that characterize the conceptual content of both fields. For instance, the dual nature of light is one of the constitutive paradoxes of quantum physics, as light can exhibit the behaviour of both waves and particles depending on the method of observation. The paradoxes of Zen Buddhism in turn juxtapose contradictory terms in the manner of synoeciosis in order to point to the notion of reality as a unified whole, as a quotation from the well-known Japanese writer on Buddhism and Zen, D. T. Suzuki, shows: 'We were parted many thousands of *kalpas* [a Vedic unit of time], yet we have not been separated even for a moment. We are facing each other all day long, yet we have never met' (quoted in Capra, p. 35).

Although the two types of knowledge appear to form another pair of binary opposites, in the context of Capra's vision they can be understood as complementary ways of approaching reality. In this sense, the new vision of nature functions as a reconciliatory theory uniting the opposites that the mystic and the physicist, the intuition and the intellect, and the complete and the incomplete knowledge, represent. 'The mystic and the physicist arrive at the same conclusion', Capra concludes, 'one starting from the inner realm, the other from the outer world' (p. 296). In order to argue that the relationship between the two is complementary rather than antagonistic, Capra makes a reference to Taoism: 'To paraphrase an old Chinese saying, mystics understand the roots of the *Tao* but not its branches; scientists understand its branches but not its roots' (p. 297). This antimetabole suggests that rather than being reducible to one another, mysticism and science can supplement each other's views, thus giving rise to a holistic worldview. In the penultimate paragraph of the book's epilogue, Capra defines their relationship though yet another antimetabole: 'Science does not need mysticism and mysticism does not need science, but man needs both' (p. 297). What this reversal of terms does is that it epitomizes Capra's call for a new kind of morality by foregrounding the importance of a holistic view of the universe for human beings, as what is at stake is no less than the survival of the species, endangered by the fragmentation of humankind's inner vision (see p. 298).

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In many ways, the ideas discussed in Capra's book are also explored in another influential popularization that seeks to explain the principles of the new physics through references to the insights of Eastern philosophies: Gary Zukav's *The Dancing Wu Li Masters*, which was published four years after *The Tao of Physics*. Like Capra, Zukav argues that one of the most profound insights that these two types of knowledge have given us is 'that we are not separate from the rest of the world as we once thought'.[28] Thus, like Capra, Zukav maintains that the insights of the new physics are of immense importance to humankind: he does not say that the survival of the species depends on a morality drawn from them but nevertheless states that when experienced in full, they are 'capable of changing us in such ways that we never again are able to view the world as we did before' (p. 16). In other words, then, here too science is claimed to have deep relevance in terms of the future of humankind.

Throughout his book Zukav argues that one of the fundamental implications of quantum physics is that humankind and the world are inseparable from each other. 'Without us,' he

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[28] Gary Zukav, *The Dancing Wu-Li Masters: An Overview of the New Physics* (New York: Morrow, 1979; New York: Bantam Books, 1980), p. 16. Further references to this book are given in parenthesis.

writes, 'or by implication, anything else to interact with, light does not exist. This remarkable conclusion is only half the story. The other half is that, in a similar manner, without light, or, by implication, anything else to interact with, *we do not exist*!' (p. 95; emphasis original). By using a loosely formulated antimetabole, the passage illustrates Heisenberg's idea that in the universe described by the new physics, there are neither independent observers nor independently observed phenomena. On this view, everything that seems to exist independently is in fact born through interaction with other things: 'We are part of nature,' Zukav notes, 'and when we study nature there is no way around the fact that nature is studying itself' (p. 31). Hence, assisted by the reciprocal logic of antimetabole, he undoes what he terms as a false opposition between 'an "I" which is "in here"' and nature that is '"out there"' (p. 30): the two antimetaboles propose that since humans are an inextricable part of the nature they are studying, it is impossible to adopt a completely objective viewpoint that would remain unaffected by the object of the study.

Because it makes a statement about the nature of the relationship between observers and the observed, this insight is closely related to the question about the truth-value of science. Zukav notes that with the formulation of the Copenhagen interpretation of quantum physics, physicists were forced to admit that the strange reality of the subatomic world did not correspond to their ideas of how reality should look like or behave — in other words, the Copenhagen interpretation showed that there could never be a perfect fit between theory and the observed reality (p. 38). Thus, they had to admit that reality contains elements that could not be apprehended directly through ordinary sense perception. In order to illustrate this, Zukav draws an analogy between the findings of the early quantum physicists and the structure of human brain: by encountering the strange reality of the subatomic realm, the pioneers of quantum physics discovered, as it were, the qualities associated with the right side of the brain (intuitiveness, irrationality, and so forth) (pp. 39–40).

Since it has succeeded in mapping previously uncharted territory, for Zukav, the quantum mechanical view of the world is capable of offering us a more complete picture of reality than the exclusively rational Newtonian physics of the left side of the brain. 'Wu Li Masters [the metaphorical teachers teaching the essence of the new physics]', he writes, 'perceive in both ways, the rational and the irrational, the assertive and the receptive, the masculine and the feminine. They reject neither one nor the other' (p. 41). Note how the passage uses synoeciosis in order to foreground the idea that reality should be understood in terms of qualities that are in a complementary rather than an antithetical relationship to each other — as Zukav later goes on to remark, 'there is a growing body of evidence that the distinction between the "in here" and "out there" is illusion' (p. 92).

Like Capra, then, Zukav uses synoeciosis as a rhetorical means of giving linguistic form to the notion of seemingly opposite qualities in a complementary relationship to each other in a manner that is reminiscent of Niels Bohr's philosophy of complementarity. Discussing the wave-particle duality of light, he notes that although light cannot exhibit both kinds of behaviour simultaneously, '*both* [types of behaviour] are necessary to understand light' (p. 93; emphasis original). In this sense the logic of complementarity is the logic of both/and rather than that of either/or: 'Not only are waves particles, […] but particles are also waves!' (p. 96) and 'Just as waves have particle-like characteristics […], particles also have wave-like characteristics' (p. 107). These antimetaboles foreground the idea that complementarity gives rise to a distinctively symmetrical universe. Explaining the convertibility of mass and energy in the special theory of relativity, Zukav makes a comparison between their relationship and various pairs of natural antonyms:

> One side of the circle is called “yin” and other side is called “yang.” Where there is yin, there is yang. Where there is high, there is also low. Where there is day, there is night. Where there is death, there is also birth. The concept of yin-yang, which is really a very old law of symmetry, is yet another way of saying that the physical universe is a whole that seeks balance within itself. (p. 158)

Although energy and mass, of course, are not natural antonyms like the other terms in the passage, their juxtaposition through synoeciosis suggests a relationship similar to the ones created by the semantic opposites. Moreover, we may observe that as used in this context, synoeciosis has the same function as antimetabole would have, since both figures aim to convey the sense of interconnectedness and balance. Indeed, it is not surprising that Zukav uses the latter figure when describing Einstein’s fundamental insight in the theory: ‘Mass may be converted into energy and energy may be converted into mass, but the total amount of mass-energy in the universe does not change’ (p. 157).

As noted above, the intertwined nature of the relationship between the observer and the observed in quantum physics is perhaps most evident in Heisenberg’s uncertainty principle. Zukav notes that at the subatomic level, our measurements of physical objects are bound to be imprecise, as ‘we reach a certain point of at which one part or another of our picture of nature becomes blurred, and there is no way to reclarify that part without blurring another part of the picture’ (p. 111). Hence, at this level the fact that there are no individual entities but only interaction becomes an insurmountable obstacle for accurate measurement. Zukav employs another antimetabole in order to illustrate this:

> As we make the final adjustments, we are astonished to discover that when the right side of the picture clears, the left side of the picture becomes completely unfocused and nothing in it is recognizable. When we try to focus the left side of the picture, the right side starts to blur and soon the situation is reversed. (p. 111)

In this passage the reversed syntax characteristic of antimetabole functions as an illustrative means of describing the kind of two-way causality that is at the heart of the uncertainty principle. Just as the observer affects the observed during measurement, then, the observed affects the observer: 'If we precisely determine the position of the particle, then, strange as it sounds, there is *nothing* that we can know about its momentum. If we precisely determine the momentum of the particle, there is no way to determine its position' (p. 111; emphasis original). In this way, the reversal of the main terms epitomizes the primary implication of the uncertainty principle for human knowledge: 'At the subatomic level, *we cannot observe something without changing it*' (p. 112; emphasis original).

Another fundamental implication of Heisenberg's discovery has to do with the concept of moving particles. Given the fact that we cannot measure the position and momentum of a subatomic particle simultaneously, we cannot literally talk about moving particles because such a concept would require that both variables be known at the same time. This means that for us observers, knowledge of such things is determined to remain partial. In order to illustrate the staggering implications of this realization for human knowledge, Zukav quotes Heisenberg's famous statement 'What we observe is not nature itself, but nature exposed to our method of questioning' (quoted in Zukav, p. 114). Through a simple textbook antithesis Heisenberg makes a profound statement concerning all our epistemological interactions with the world: when approaching the subatomic realm, we cannot make a clear-cut distinction between the observer and the observed, as the interaction between the two necessarily makes their boundary vague.

Such interaction manifests itself also in the mutual relationships of subatomic particles. Noting how new particles are constantly created in collisions, Zukav writes that 'the subatomic world is a continual dance of creation and annihilation, of mass changing to energy and energy changing to mass' (p. 197). In this short yet rhetorically rich passage, we may detect three figures of speech that all have a specific, important function. Firstly, like Capra's idea of the quantum field as an endless cosmic dance, it introduces the metaphor of the world of matter as dance. Secondly, it illustrates one of the main implications of this metaphor through synoeciosis: in the dance of particles, creation, and annihilation are complementary rather than antithetical activities. Thirdly, the antimetabole at the end of the passage implies that the relationships between the dancers, subatomic particles, are based on creative interaction that ties them together.

Moreover, as is obvious in this example, one of the main functions of the dance metaphor is to foreground the idea that at the level of subatomic particles, dichotomies such as the one between creation and annihilation cease to exist. Indeed, Zukav states that 'in particle physics there is no distinction between empty […] and not-empty, or between something and not-something' (p. 194). Instead, he argues, 'the world view of particle physics is a picture of *chaos beneath order*' (p. 194; emphasis original). The italicized phrase again employs the form of synoeciosis: instead of picturing chaos and order as antithetical entities, it invites readers to consider their relationship in terms of complementarity rather than exclusion. What the figure also does is that it gives a rhetorically persuasive form to the idea that the worldview of quantum physics has inverted some of the fundamental assumptions of the previous paradigm: Zukav notes that ‘the old world view [of classical physics] was a picture of order beneath chaos’ (p. 194). In contrast to the view of physical bodies following their predetermined paths in the macroscopic world, then, the microscopic entities exist in a stochastic universe of continuous transformation.

The dance metaphor also indicates that the dance of particles is basically an interactive phenomenon. This means that we cannot really picture particles as separate entities in possession of immutable identities. As a result, Zukav notes, ‘*physical reality is essentially nonsubstantial*’ (p. 200; emphasis original), so that instead of matter having concrete existence, it has a tendency to exist in the form of fields described by quantum field theory. In order to epitomize this fact, Zukav uses antithesis to make a clear distinction between matter as it is commonly thought and the interactive quantum fields: ‘According to quantum field theory, fields alone are real. *They* are the substance of the universe and not “matter”’ (p. 200; emphasis original). Hence, Zukav’s antithesis expresses another conceptual inversion born out of the strangeness of the quantum world: although everyday thinking sees matter forming the fundamental basis of all existence, quantum physics shows that the substantial nature of matter is an illusion, as the real reality is created by the insubstantial quantum fields. Therefore, Zukav argues, the question about the ultimate essence of matter becomes meaningless — or, at any rate, impossible to answer. He uses a descending series in order to illustrate this idea:

> Suppose, for example, that we ask of an ordinary toothpick, “What is it made of?” The answer of, of course, is “wood.” However, the question itself has taken us into a hall of mirrors because now we can ask about the wood, “What is it made of?” Closer examination reveals that wood is made of fibers, but what fibres are made of is another question, and so on.

> […].
> Physicists are people who have pursued tenaciously this endless series of questions. What they have found is startling. Wood fibers, to continue the example, are actually patterns of cells. Cells, under higher magnification, are discovered to be patterns of atoms, and, lastly, atoms have turned out to be patterns of subatomic particles. In other words, "matter" is actually a series of *patterns out of focus*. The search for the ultimate stuff of the universe ends with the discovery that there *isn't any*. (p. 193; emphases original)

In this passage gradatio provides the appropriate linguistic form for Zukav's reasoning. Its characteristic repetition that links together the items in the series conveys the idea of more or less infinite, mirror-reflecting-mirror type of recursion. Instead of concrete matter, then, at the fundamental level of physical existence there are only 'interactions of energy with energy' (Zukav, p. 193), as subatomic particles continuously collide with each other. It is in this state of affairs that we again encounter the collapse of the logic of either/or, which is so characteristic of subatomic events: using synoeciosis-like structures — the words around the coordinating conjunctions do not strictly speaking represent semantic opposites — Zukav states that 'there is no longer a clear distinction between what is and what happens, between the actor and the action. At the subatomic level the dancer and the dance are one' (p. 193).

In this sense, like the phrase *chaos beneath order*, the term *quantum field theory* is suggestive of the essentially paradoxical nature of the subatomic world. From the viewpoint of rhetoric, it consequently represents yet another union of contraries: while the word *quantum* means a part of 'an indivisible whole' (Zukav, p. 200), *field*, of course, refers to a whole rather than a part. Like synoeciosis, the term thus juxtaposes two concepts that are often viewed in opposition to each other. However, given the complementary nature of such paradoxes at the subatomic level, it is obvious that the dichotomy is only apparent, and Zukav illustrates this point through reference to qualities found in the macroscopic world: ‘In human terms, [understanding the subatomic world] means that the same person can be good *and* evil, bold *and* timid, a lion *and* a lamb (p. 201; emphases original). As in other similar cases, such as the examples of quantum paradoxes discussed by Capra, then, synoeciosis appears to be an apt means of linguistically portraying the logic of both/and that characterizes relationships in the subatomic world. (In contrast, traditional everyday thinking often seems to rely more heavily on the logic of either/or.)

Indeed, most likely influenced by the approach taken by writers such as Capra, Zukav discusses what he sees as similarities between the paradoxes of quantum physics and Zen Buddhist koans, riddles designed to help students transgress the simplistic either/or logic. ‘According to eastern philosophy in general,’ he notes, ‘opposites, such as good-bad, beautiful-ugly, birth-death, and so on, are “false distinctions”. One cannot exist without the other. They are mental structures which we have created’ (p. 205). In addition to the examples discussed above, one such paradox is the concept of *massless particle*, which is used to describe particles that have no rest mass, such as photons and the hypothetical gravitons. However, if we study these kinds of concepts from the viewpoint of rhetoric, it is clear that they can be regarded as instances of oxymoron: because we are used to regarding particles as objects that have a definite mass, a term like *massless particle* obviously represents a contradiction in terms. The form of oxymoron, however, suggests a paradoxical juxtaposition of both an object and the quality of a non-object that aligns itself with the logic of both/and.

It is therefore not surprising to discover that the analogy that Zukav draws between the microscopic and the macroscopic is to a considerable extent based on the idea of shared paradoxical aspects existing at the fundamental level of matter. ‘Hindu mythology’, he writes,

> is virtually a large-scale projection into the psychological realm of microscopic scientific discoveries. Hindu deities such as Shiva and Vishnu continually dance the creation and destruction of universes while the Buddhist image of the wheel of life symbolizes the unending process of birth, death, and rebirth which is a part of the world of form, which is emptiness, which is form. (p. 217)

Note how the passage uses synoeciosis (*the dance of creation and destruction*) to illustrate the principle of complementarity. Its end in turn foregrounds the same idea by linking form and emptiness to each other in a circular fashion.

Zukav discusses this notion of two opposite concepts linked to each other in complementary fashion in more detail when he introduces the metaphor of Indra’s net. Referring to ‘a vast network of gems which overhangs the palace of […] Indra [the god of war and storm in Hinduism]’ (Zukav, p. 238), the metaphor represents a means of portraying the subatomic world as an interconnected network. In this network, according to *The Flower Garland Sutra* of Mahayana Buddhism, ‘each object […] is not merely itself but involves every other object and in fact *is* everything else’ (quoted in Zukav, p. 239; emphasis original). He proceeds to illustrate the meaning of the metaphor by quoting *The Heart Sutra* of Mahayana Buddhism, which states that ‘form is emptiness, emptiness is form’ (quoted in Zukav, p. 240). Using the form of antimetabole, the passage thus articulates the idea presented through the reference to the Buddhist wheel of life: seemingly opposite concepts such as form and emptiness can only be defined in relation to each other, with each concept being both itself and the other concept. Accordingly, Zukav sees in particle interaction ‘an exquisite dance of emptiness becoming form and form becoming emptiness' and, following the same logic, argues that 'vacuum diagrams [Feynman diagrams depicting the interactions of particles in a vacuum] are representations of remarkable transformations of "something" into "nothing" and "nothing" into "something"' (p. 241).

Because of its strong insistence to describe the subatomic world in terms of a network of relationships, it is not surprising that like *The Tao of Physics*, *The Dancing Wu-Li Masters* implicitly calls for a holistic vision of the universe. In the chapter 'More Than Both', Zukav argues that although 'the physical world [seems to consist] of many separate parts' (p. 255), the parts are in the end 'manifestations of the same whole' (p. 256). He finds the scientific proof for this essentially metaphysical statement in the so-called Bell's theorem. Originally published in 1964 by the British physicist John S. Bell, the theorem argues against the claim that the quantum mechanical description of nature is incomplete, a proposition first put forth by Einstein, Podolsky, and Rosen in their famous 1935 paper 'Can quantum-mechanical description of physical reality be considered complete?' and later by physicists such as David Bohm. In short, the views arguing for the incompleteness of the orthodox quantum theory suggest that there is an objective foundation behind the level of indeterminacy, a deeper level of reality, so to speak. However, the most important implication of Bell's theorem for Zukav's own argument is the suggestion that the microscopic and the macroscopic share one fundamental characteristic: irrationality. Bell's theorem, Zukav states,

> says that not only do events in the realm of the very small behave in ways which are utterly different from our commonsense view of the world, but also that events in the world at large, the world of freeways and sports cars, behave in ways which are utterly different from our commonsense view of them. (pp. 290–91)

One hypothetical example of such behaviour that Zukav mentions is the argument that Bell's theorem proves false the principle of locality, which Einstein and company championed in their paper: while the principle of locality states that distant objects cannot directly influence each other, Bell's theorem suggests that two separate objects in space are able to interact without a mediator. Consequently, Zukav argues that

> what happens here is intimately and immediately connected to what happens elsewhere in the universe, which, in turn, is intimately and immediately connected to what happens elsewhere in the universe, and so on. (pp. 296–97)

Note how the passage uses gradatio to linguistically convey the idea of everything being connected to everything else. Through the repetition of the phrase *what happens here is intimately and immediately connected to*, it creates the image of an infinite series of items connected to each other, as also suggested by the metaphor of Indra's net.

In addition to rhetorical tools such as gradatio, Zukav employs repetition to illustrate the idea that the microscopic and the macroscopic are both essentially interactive networks of objects: 'That which is is that which is. That which is not is that which is. There is nothing which is not that which is. There is nothing other than that which is. Everything is that which is. We are a part of that which is. In fact, *we are that which is*' (p. 282; emphasis original). While the first sentence in the passage features the use of a figure of repetition known as epanalepsis, which repeats the beginning of the sentence at its end, the remaining sentences employ epistrophe, the repetition of the endings of successive structures. In the same way, discussing David Bohm's notion of the parts of the universe forming an 'unbroken wholeness', he notes that it is difficult for us to understand the world in such terms because we habitually conceptualize it through the logic of either/or:

According to this mode of thought, only Being *is*. Therefore, Non-being *is not*. This way of thinking gives us a practical tool for dealing with the world, but it doesn't describe what happens. Actually, Non-being also *is*. Both Being and Non-being are that-which-is. *Everything*, even "emptiness" is that-which-is. There is nothing which is not that-which-is. (p. 308; emphases original)

By subjecting Being and Non-being to the concept of that-which-is — which is again repeated through the use of epistrophe — Zukav foregrounds the idea that the network of interactive objects is based on complementary relationships instead of antithetical ones. In this sense, it exemplifies the logic of both/and by proposing that the relationships of the parts not only constitute the whole but also are the whole.

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Having discussed Capra's and Zukav's use of figurative language in their attempts to build a bridge between two types of knowledge, I now turn to a book that instead of trying to create a link between Western science and Eastern philosophies seeks to describe human personality and consciousness through the ideas of quantum physics: the psychiatrist and psychologist Danah Zohar's *The Quantum Self*. Arguing that 'like elementary particle systems, we too — our personalities, our selves — are quantum systems',[29] Zohar finds in the theories of contemporary physics a scientific foundation for her exploration of various philosophical and metaphysical topics, including consciousness, the relationship between the mind and the body, the self and its relationship to others, immortality, freedom of will,

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[29] Danah Zohar, *The Quantum Self* (London: Bloomsbury, 1990; London: HarperCollins, 1991), p. 114. Further references to this book are given in parenthesis.

creativity, aesthetics, and divinity. Of these the problem of consciousness is especially important for her: 'It is the central argument of this book that we conscious human beings are the natural bridge between the everyday world and the world of quantum physics', she states, 'and that a closer look at the nature and role of consciousness […] will lead to a deeper philosophical understanding of the everyday and to a more complete picture of quantum theory' (p. 6). What follows from this is that for Zohar the macroscopic world of human existence and the microscopic world of subatomic particles are mirrors of each other, since the same quantum processes govern both (p. 6).

As in the case of so many representatives of what Martin Eger calls the new epic of science,[30] Zohar's exploration of the human relevance of science has a definite socio-philosophical, reconciliatory purpose: to alleviate the sense of alienation in society, which, according to her, springs from our flawed understanding of fundamental relationships, such as that between mind and matter. Noting that individuals in contemporary society suffer from an acute sense of alienation and separation, Zohar identifies problematic dichotomies such as those between mind and body, the individual and society, and nature and culture as the main sources of their sentiments (pp. 217–19). In order to overcome these kinds of problems, she suggests, we must turn to quantum physics in order to realize that the dichotomies are illusory rather than real:

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[30] Writing in 1993, Eger defines this as 'literature which has come to the fore during the past quarter century or so, mostly full-length books combining high-quality writing with scientific depth. Typically it deals with subjects that have philosophical or social or humane implications. It is aimed neither at the specialist nor at the casual reader. It is a body of writing in which scientific and literary seriousness are blended and offered up consciously in an attempt to break through professional barriers with a message deemed important enough to be worth the effort of *demanding* reading'. Martin Eger, 'Hermeneutics and the New Epic of Science', in *The Literature of Science: Perspectives of Popular Scientific Writing*, ed. by Murdo William McRae (see McRae, above), pp. 186–209 (p. 186). Further references to this article are given in parenthesis.

> It is my conviction that in quantum physics we now have the foundations of physics upon which we can base both our science and our psychology, and that through a wedding of physics and psychology we, too, can live in a reconciled universe, a universe in which we and our culture are fully, and meaningfully, part of the scheme of things. (p. 7)

In its desire to achieve reconciliation between two different types of knowledge, *The Quantum Self* resembles much the efforts of Capra and Zukav, who aim at the unification of Western and Eastern worldviews.

Zohar proceeds to reconcile the opposition between mind and body — or, in general, the opposition between consciousness and matter — by discussing the views she wants to argue against. She first cites Descartes's observation that 'it is […] certain that I am truly distinct from my body, and can exist without it' (quoted in Zohar, p. 74) and sums up the materialist argument about the relationship between the two by using gradatio: 'For something to exist […] it must be substantial, the substantial is the physical, and the physical is made out of matter which in turn is made out of atoms' (p. 77). The descending series thus exemplifies the idea that for the materialist, mental phenomena are ultimately reducible to the smallest constituents of matter.

After dismissing both dualistic and materialistic accounts of the relationship between mind and body as inadequate, Zohar goes on to talk about the philosophical position that best supports her own views: a 'limited panpsychism' (p. 78).[31] 'If bodies without minds are too brute,' she says of the faults of dualism and materialism, 'and minds without bodies too ethereal, perhaps there is no way they can be separated after all. Perhaps the mental is

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[31] In short, although it entails various positions, panpsychism argues that all matter is to some degree constituted by mind, thus being sentient. In this sense, it derives from idealism, which holds that mind is the fundamental essence of reality. William Seager and Sean Allen-Hermanson, 'Panpsychism', in *The Stanford Encyclopedia of Philosophy*, online edn, ed. by Edward N. Zalta, 2005 <http://plato.stanford.edu/archives/sum2005/entries/panpsychism/> [accessed 30 May 2006].

really a basic property of the material and vice versa' (p. 78). The last sentence uses an implied antimetabole to suggest that mind and body are inseparable from each other, thus foregrounding their mutual interdependence in panpsychism.

What follows from this is that in Zohar's account, there is no antithetical relationship between conscious and not-conscious beings. Instead consciousness — or mind — is an all-pervasive phenomenon that exists as a continuum consisting of different types of consciousnesses. She illustrates this idea by drawing a link between mind and the relationship between fermions (electrons, protons, and neutrons) and bosons (photons, +/- z particles, neutral z particles, gluons, and gravitons), the two types of particles in the subatomic world. While the former are 'individuals' with no complete overlap of wave functions, the latter 'surrender all claims to individuality' (p. 86) because their wave functions are capable of overlapping completely. However, despite these differences, Zohar argues, their 'mutually creative dialogue' gives rise to the notion of mind and matter as inseparable entities:

> Without bosons, fermions would seldom get together and build anything; without fermions, bosons would have nothing to draw into relationship and thus nothing with which to order and structure their own more complex coherence. (p. 206)

As we can see, in this passage Zohar again uses antimetabole's reversal of the main terms in order to foreground their causal interdependence. She suggests that because fermions are the building blocks of matter and bosons 'the most primary antecedent of consciousness' (p. 206), mind and matter are interdependent phenomena already at the level of subatomic particles. In this way, she is able to establish a rhetorically persuasive argumentative basis for her view that life is characterized by different degrees of consciousness, from subatomic particles to human beings.

Zohar strengthens the sense of interdependence by making an analogy between the relationship between mind and body, and the relationship existing between the two modes of particle existence. '*The wave/particle duality of quantum 'stuff''*, she writes, '*becomes the most primary mind/body relationship in the world and the core of all that, at higher levels, we recognize as the mental and physical aspects of life*' (p. 80; emphasis original). Just as the two complementary modes of particle behaviour are inseparable from each other at the subatomic level, mind and body are complementary phenomena in the world of human beings. Thus, conceiving the microscopic and the macroscopic as metaphorical mirrors of each other, Zohar goes on to build a similar comparison between humankind and the universe. At the fundamental level of its existence, she argues, the former is a microcosm of the latter:

> We are, in our essential being, made of the same stuff and held together by the same dynamics as those which account for everything else in the universe. And equally […] the universe is made of the same stuff and held together by the same dynamics as those which account for us. (p. 83)

This passage employs antimetabole in order to establish a link between the main terms. Basically, it argues for correspondence between two types of complementarity: since the mind-body complementarity in humans is analogous to the wave-particle complementarity in matter, the individual and the universe are reflections of each other, just as both are products of quantum events. Since humankind is an inseparable part of the universe, Zohar sees the individual self as a quantum self, a self partaking of the same fundamental physical processes as the world surrounding it.

After having argued for the inseparability of mind and matter, Zohar turns to the question of identity, which she sees being closely linked to the problem of consciousness. ‘The unity of the person, or his supposed unity’, she writes, ‘is much the same problem as the more basic unity of consciousness’ (p. 90). More specifically, the dilemma lies in deciding what it is that actually constitutes individual identities: Zohar’s main argument concerning identity is that what we call the self is a composite of many subselves, and as such, it is a much more fluid entity than we would normally think. In order to describe the self in a way that can best account for its fluid, dynamic nature, she makes a comparison between subatomic particles and human beings:

> Like the self, elementary particle systems are wholes within wholes, or ‘individuals’ within ‘individuals’. Because of the wave/particle duality, the constituent members of particle systems carry at all times the properties of both waves and particles. With their particle aspect they have the capacity to be something in particular which can be ‘pinned down’, if only briefly and only somewhat. With their wave aspect they have the capacity to relate to other ‘individuals’ through the partial overlapping of their wave functions. Through their relationships, their overlapping wave functions, some of their qualities merge in such a way that a new whole is formed. (p. 95)

In this passage the simile indicating a comparison between the self and the characteristics of particles makes the fluid and endlessly fluctuating quality of the latter constitutive of the former. The analogy also supports Zohar claim that materialism’s reductionist view of the self is wrong. The self, the sense of I, is really unity in multiplicity, as it consists of various subselves whose level of integration fluctuates continuously, and for this reason the properties of the whole that they form cannot be reduced to the properties of the constituents themselves (pp. 95–96).

Although this might suggest that the self is a fragmented, messy affair, Zohar argues that there is a factor that provides continuity for our experience of the various subselves:

memory. In order to show how the relationship between the self and memory has been misunderstood in earlier theories, she discusses the British philosopher Derek Parfit's theory that treats memory and the self as two separate things. Because for Parfit the self is reducible to the ever-changing brain states of the individual, there is no continuity between selves that occupy different positions in time: 'If I say, "It will not be me, but one of my future selves," I do not imply that I will be that future self. […]. There is no underlying person who we both are' (quoted in Zohar, p. 101). However, for Zohar, who sees both individuals and particles in terms of relationships, the lack of continuity between different selves makes Parfit's view 'too disjointed and Newtonian' (p. 101). Thus, as in the case of the dichotomy between consciousness and matter, she proceeds to link the terms to each other by treating both as manifestations of quantum phenomena, so that just as various selves overlap each other in the model of the quantum self, also the memories of the successive selves overlap each other in Zohar's model of the so-called quantum memory. It is this kind of memory that provides continuity to the individual experience of the self, as the person's present I is shaped by a constant 'dialogue with the past [selves]' (p. 104). Once again making a comparison to the behaviour of particles, Zohar notes that the dialogue resembles the way in which 'the wave functions of two elementary particles overlap to form a new quantum system' (p. 102) — the selves of the individual are thus born out of the overlap of one's memories of the past and the present consciousness. Foregrounding the notion of identity and memory as inseparable concepts, she epitomizes the idea of the dialogic nature of the self through antimetabole: 'My relived past can no more be separated from my present than my present can be separated from my past' (p. 106).

Having established a link between the self and memory, Zohar proceeds to discuss the nature of the relationships that individuals form between themselves. She argues that many of the problems concerning our understanding of relationships stem from a ‘tension’ between the incompatible philosophical positions of those that support ‘the philosophy of radical individualism’ (p. 108) and those that emphasize the status of the individual as a product of history and society. As in the case of the dichotomies discussed above, Zohar aims to overcome the problems of this opposition by opening up a middle ground between the antagonistic views.

Aiming to show that individuals are neither fundamentally separated from each other and the world nor exclusively products of their relationships between each other and the world, Zohar returns to the idea of the quantum self and claims that because of its fluid and dynamic nature, ‘there is no clear way to say where “I” end and “you” begin’ (p. 121). In order to illustrate this claim, she again draws a comparison between the world of subatomic events and that of human affairs:

> People involved in an intimate relationship can share each other’s characteristics, as in projective identification, or they can trade characteristics, as happens in role reversals. The latter can be accounted for by a quantum resonance phenomenon in which two coupled quantum systems (or two non-locally related quantum systems), each with its own characteristic oscillation, suddenly swap oscillations. In this case, I would become you and you me. (p. 120)

With its focus on interaction in both microscopic and macroscopic worlds, the passage foregrounds the interchangeable nature of both particles and human identities. Note also how the reversal of terms in the antimetabole of the last sentence emphasizes the notion of the self as a constant dialogue between the individual and others. (The dynamic nature of such dialogue is described earlier in the book through synoeciosis, which pairs semantic opposites such as ‘rise and fall’, ‘construction and decline’, ‘emergence and return’, and ‘beginning and ceasing’ (p. 13).) Accordingly, then, for Zohar the logic of interpersonal relationships reflects the logic of both/and rather than that of either/or. ‘We need to see’, she writes, ‘how it is […] that “we” can be both a compound of “I” and “you” *and* a new thing in itself with its own qualities’ (p. 113; emphasis original).

The notion of the self as a product a continuous process of interaction with others and the world is also evident in Zohar’s discussion on the relationship between the self and time. ‘On a quantum view’, she writes, ‘there is no way to draw any sharp distinction between my persistence through time, my close relationship to others, and my survival after death’ (p. 131). Zohar illustrates how individuals are inextricably interwoven in the texture of reality by once again comparing humans to particles:

> Like electrons, each of us is a ‘point source’ in space and time (our particle aspect) and at the same time a complex pattern woven from our co-mingling with others (our wave aspect). We, too, are patterns of active energy, patterns arising from within ourselves (our genetic code, the structure of our bodies, our sense and all our experience) and from beyond ourselves (the structure and experience of others, many of whom have lived before us and others who will live after). For each of us, there is no clear way to say where that pattern begins or ends. ‘In my beginning is my end’, but also, ‘In my end is my beginning’. (p. 132)

In addition to using simile and metaphor for strengthening the analogy between the microscopic and the macroscopic, the passage contains a quotation from the first and last lines of T. S. Eliot’s *East Coker* (1940) for the same aim. Eliot’s antimetabole, which he uses to describe the paradoxical relationship between life and death, suggests that the individual sense of I is continuously shaped by interaction with others through time. At the end of her argument Zohar employs another antimetabole to express the idea that this kind of interaction includes not only other human beings but also the universe: ‘I am made of the stuff of which the universe is made and the universe shall be made of me’ (p. 133).

The notion of the individual being inextricably linked to the stuff of the universe can also be seen in Zohar’s example of a child and a clay pot, which she uses to illustrate her argument concerning the relationship between the individual and the world. After stating that through their dialogic involvement with the material world individuals ‘transform’ not only that world but also themselves, she goes on to describe the situation as follows: ‘Without the child’s conscious intention, the clay would never have become a pot, but equally, without that pot, the child’s sense of beauty would never have incarnated’ (p. 186). Hence, by again using antimetabole to reverse the main terms in order to foreground their interdependent relationship, Zohar is able to make rhetorically more persuasive her argument that instead of being fundamentally separated from the rest of the world, humans engage in continuous creative interaction with their surroundings. Like the analogy linking human and particle interaction, the antimetabole reconfigures the dichotomy between the individual and the world by suggesting that neither the former nor the relationship of the former to the latter should be considered primary, as the sense of individual self is fundamentally an outcome of the self’s interaction with the world.

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To sum up, a significant feature in the rhetoric of the writers analysed above is that they tend employ figurative language that places emphasis on concepts such as unity, interaction, and dynamism. Capra and Zukav repeatedly use synoeciosis, oxymoron, antimetabole, gradatio, and various figures of repetition in order to linguistically accommodate the notion of the universe as a dynamic, interlinked web in which seemingly contradictory concepts are united. In doing so, they espouse the logic of complementarity — the logic of both/and — which acknowledges the idea presented in various schools of Eastern metaphysics that underlying the fragmentation of the modern world, there is an unbroken wholeness. Zohar in turn uses mostly antimetabole in order to establish a link between consciousness and the subatomic world, arguing that the interaction between the subselves of the individual self and the interaction between elementary particles mirror each other. She also employs the same figure to portray the relations between both individuals and the individual and the macroscopic world and proposes that there are no sharply defined boundaries between parts and wholes, as they exist on a continuum of consciousness that ranges from subatomic particles to the universe.

Next, let us see how the use of such syntactic forms establishes a link to the representation of quantum physics in contemporary fiction and drama.

2.2.2 Uncertainties and Quantum Selves

Having analysed how best-selling popularizations on the new physics have found in the subatomic an apt model for approaching the human concerns of knowledge and identity, I now turn to discuss how contemporary literature has approached the ideas of the new physics.[32] I begin by considering similar topics in Jeanette Winterson's *Gut Symmetries*, a

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[32] For discussion on the relationship between the new physics and literature, see also Robert Nadeau's *Readings from the New Book on Nature: Physics and Metaphysics in the Modern Novel* (Amherst: The

novel that establishes a close link between the world studied by quantum physics and the world of human affairs. Quite a typical novel for Winterson, it explores issues familiar from her other novels, including the nature of history, the experience of time, the binary logic of the Western culture, the relationship of fact and fiction, the relationship between different types of knowledge, and the question of identity.[33] More pronounced than in her other work, however, is her extensive use of certain scientific ideas that form the underlying conceptual basis for the exploration of these issues. In their discussion on the various kinds of discourses — scientific, pseudoscientific, and sexual — in the novel, the critics Helena Grice and Tim Woods note that *Gut Symmetries* represents 'another reworking of the urge to discover a fundamental structure to all the natural phenomena in the universe'.[34] Yet this

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University of Massachusetts Press, 1981) and Susan Strehle's *Fiction in the Quantum Universe* (Chapel Hill: University of North Carolina Press, 1992).

[33] During the last ten years or so, Winterson's novels have become objects of academic study because of their relevance to important issues in contemporary literary and cultural studies such as the fictional nature of history, the problem of linguistic reference, the relationship between the text and the reader, and the politics of sexuality. Helena Grice and Tim Woods, 'Reading Jeanette Winterson's Writing', in *'I'm telling you stories': Jeanette Winterson and the Politics of Reading*, Postmodern Studies, 25, ed. by Helena Grice and Tim Woods (Amsterdam: Rodopi, 1998), pp. 1–11 (pp. 1–2). For Linda Hutcheon, the affinity of Winterson's novels to postmodernism is apparent particularly in the way they approach the question of history: because they emphasize the status of history as a discourse with a recognizable ideological content, the novels are 'historiographic metafictions', narratives that display the qualities of self-reflexivity and historical awareness. Linda Hutcheon, *A Poetics of Postmodernism* (London: Routledge, 1989), p. 5. Yet another distinct link to recent theoretical discussions can be found in Winterson's treatment of space and time: the critic Lyn Pykett, for instance, notes how the novels *Oranges Are Not the Only Fruit* (1985), *The Passion* (1987), and *Sexing the Cherry* (1989) 'repeatedly "demonstrate" […] a distrust of the possibility of mapping and measuring space and time'. Lyn Pykett, 'A New Way with Words? Jeanette Winterson's Post-Modernism', in *'I'm telling you stories': Jeanette Winterson and the Politics of Reading*, (see Grice and Woods, above), pp. 53–60 (p. 54). Placed in the context of the theoretical framework of postmodernism, this distrust reflects the way in which postmodernist theory and fiction question simplistic approaches to knowledge and representation. Pykett, pp. 53–60 (pp. 54–55).

[34] Helena Grice and Tim Woods, 'Grand (Dis)Unified Theories? Dislocated Discourses in *Gut Symmetries*', in *'I'm telling you stories': Jeanette Winterson and the Politics of Reading*, (see Grice and Woods, above), pp. 117–26 (p. 117). Further references to this article are given in parenthesis. On the one hand, the title of the novel obviously alludes to grand unified theories (GUTs) in contemporary physics that seek to give a single explanation of the electromagnetic, strong, and weak interactions between subatomic particles. On the other hand, the title may be seen as a reference to the fundamental emotional forces that drive human existence, such as love and sexual desire.

urge is countered by a manifest — if stereotypical — rejection of essentialism, which is especially evident in the opposition that the story sets up between two antagonistic ways of viewing and knowing the world: the scientific (rational) and the mystical (irrational).

Structurally, the clash of the two worldviews emerges from characterization. The novel features three main characters, who take turns as narrators. Alice is a theoretical physicist who has boarded the *QE2* for an overseas journey to the United States. During the journey she lectures on the relationship between the new physics and esoteric thought and begins an affair with Jove, a masculine and rational theoretical physicist working on 'a new model of the cosmos, dimensionality of hyperspace [and] ghost universes'.[35] When they reach New York, Alice meets Jove's wife, the mystically minded and unstable Stella, and becomes also her lover. Hence, while Jove and Stella to a considerable extent embody qualities associated with the opposition of rationalism (masculinity, rationality, and stability) and mysticism (femininity, irrationality, and instability), Alice, with her interest in both science and the occult, appears to symbolize their reconciliation.

By setting Jove and Stella against each other in terms of their qualities — significantly, throughout the story their relationship is a stormy one — and Alice as their lover, Winterson, like Fritjof Capra and Gary Zukav, seeks to build a conceptual bridge between two apparently opposing systems of thought. In a manner similar to that of Capra and Zukav, Alice's lengthy expositions on the subjects of her lectures foreground the notion of the scientific and the esoteric as each other's mirrors. For instance, both contemporary physics and Renaissance alchemy appear to regard reality as an undivided totality:

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[35] Jeanette Winterson, *Gut Symmetries* (London: Granta, 1997; 1998), p. 15. Further references to this book are given in parenthesis.

> The Miracle of the One that the alchemists sought is not so very far from the infant theory of hyperspace, where all the seeming dislocations and separations of the atomic and sub-atomic worlds are unified into a co-operating whole. (p. 2)

As the passage clearly indicates, at the heart of both Alice's lecture and the novel itself is the notion of theory — be it scientific or esoteric — as a more or less complete description of the essential structure of the individual psyche and the world. In the same way, Alice establishes a link between the Pythagorean notion of 'the universe as a musical instrument, vibrating divine harmonies' (p. 98) and the superstring theory, a grand unified theory that seeks to give one all-encompassing theoretical explanation of all fundamental particles and forces by describing them as infinitesimally small strings of vibrating energy. 'Following the Superstring theory', she notes, 'the symmetry we observe in our universe in only a remnant of the symmetry to be observed in perfect ten-dimensional space' (pp. 98–99), thus envisioning the universe as a whole containing correspondent parts from the smallest building blocks of matter to the galaxies.

Since humankind is a part of the interconnected physical reality, it follows that also the individual and the universe are reflections of each other. Speaking of the esoteric theories of the Renaissance alchemist and occultist Paracelsus, Alice notes that the Swiss physician 'was a student of Correspondences: "As above, so below." The zodiac in the sky is imprinted in the body. "The galaxa goes through the belly"' (p. 2).[36] Like Danah Zohar,

[36] The phrase *As above, so below* derives from the so-called *Emerald Table* (*Tabula Smaragdina*), a short esoteric text attributed to Hermes Trismegistus, a mythical religious and philosophical authority appearing in Medieval and Renaissance writings on alchemy. Interestingly, some of its translations use an exemplary antimetabole to capture the notion of the microcosm and the macrocosm forming a unified whole: 'That which is above is like to that which is below, and that which is below is like to that which is above, to accomplish the miracles of one thing.' Hermes Trismegistus, *The Emerald Table* (*Tabula Smaragdina*), in *The Alchemy Reader: From Hermes Trismegistus to Isaac Newton*, ed. by Stanton J. Linden (Cambridge: Cambridge University Press, 2003), pp. 27–28 (p. 27).

whose rhetoric emphasizes the inseparability of the individual and the universe, she argues for a close link between the two. As parts of an interconnected whole, the microscopic and the macroscopic are one:

> If the Superstring theory is correct there is no table. There is no basic building block, no firm stable first principle on which to pile the rest. The cups and saucers are in the air, the cloth levitating under them, the table itself is notional, we would feel uncomfortable eating our dinner without it, in fact it is a vibration as unsolid as ourselves. (p. 159)

The passage quite clearly draws an analogy between the individual and the universe. Composed of the same matter, they are united by virtue of being parts of the same underlying whole. Through her comparison Alice also makes a direct comment on the nature of human identity, suggesting that in the sense of it being a manifestation of vibrating energy, it does not seem to possess any fundamental essence. In this way, then, she finds in the new physics justification for an essentially anti-essentialist model of the self.

However, while some strands of postmodern thought would find such anti-essentialism highly laudable, the idea that human identity has no solid basis proves to be a major source of anxiety for the characters of *Gut Symmetries*. This is especially true of Alice, whom the speculative theories of contemporary physics continuously force to question the nature of her own identity and self. Pondering on her relationship to the world, she is overcome by a sense of instability. ‘Those well-built trig points,’ she observes,

> those physical determinants of parents, background, school, family, birth, marriage, death, love, work, are themselves as much in motion as I am. What should be stable, shifts. What I am told is solid, slips. (pp. 9–10)

Alice's confusion about her identity is particularly evident in Winterson's use of the image of the mirror, a common metaphor for the individual self: 'What or who? I cannot name myself. […]. The hall of mirrors set around me has been angled to distort. Everywhere I go, reflection. Everywhere a caught image of who I am. In all of that who am I?' (p. 12). In this way, the novel models the macroscopic world of its characters' lives after the fluid and ephemeral world of subatomic particles, suggesting that Alice's main problem is that she cannot relate to the world in meaningful terms and is thus unable to experience the same kind of unity that her theories describe.

As it portrays both physical reality and identity as fluid processes rather than stable phenomena, it is not surprising that the novel links them closely to its exploration of time. Following the speculations of contemporary physics, Alice denies the commonsense assumption that time — and human life in general — unfolds as a linear sequence from the past towards the future. 'If the universe is movement', she muses, 'it will not be in one direction only. We think of our lives as linear but it is the spin of the earth that allows us to observe time' (p. 218). Instead of a linear progression, she envisions the past and the future intertwined in the present moment ('History and futurity are now' (p. 219)), replacing the Newtonian metaphor for time, the arrow, by an image of a twisting and turning river:

> A river cannot flow against its current, but it can flow in circles; its eddies and whirlpools regularly break up its strong press forward. The riverrun is maverick, there is a high chance of cross-current, a snag of time that returns us without warning to a place we thought we had sailed through long since. (p. 104)

The notion that the past, the present, and the future are inseparable from each other impinges on the question of identity, as is evident in the life history of Alice. Noting that ‘only in the present do I begin to recognise my own past’ (p. 200), she imagines individual histories as streams in the river:

> My time, my father’s time, my grandmother’s time. Now separate, now flowing together, and joined with the floods and cries of men and women I have never met, places and years that snag their movement in mine and choose me, for a moment, as a conscious depot of history. (p. 218)

Through their synoeciosis-like juxtaposition of opposite concepts (*present* and *past*, *separate* and *together*), Alice’s words point to the paradoxical logic of both/and, which in the novel characterizes relationships and individual identity in the macroscopic world. Reminiscent of Zohar’s idea of the quantum self, the passage suggests that the individual’s past and present are in a dialogue with each other, continuously moulding the self. Indeed, Alice’s present is moulded by her past, which catches up with her in her relationships. ‘It had been the same with my father’ (p. 104), as she observes of her affair with Jove.

What is notable in this is that instead of the various selves of the individual remaining separate from each other, their boundaries overlap, causing new selves to emerge from the interplay of the memories of the past and the consciousness of the present moment. This idea again foregrounds the fluidity of the individual self, which is more akin to a process than a static phenomenon, and as such creates even more anxiety in the minds of the novel’s characters: ‘The past comes with us and occasionally kidnaps the present, so that the distinctions we depend on for safety, for sanity disappear. […]. When this happens we are no longer sure who we are, or perhaps we can no longer pretend to be sure who we are’ (p. 105). Rather than celebrating the sense of fluid identity that the collapse of the boundaries between the past and the present creates, the characters in *Gut Symmetries* are constantly troubled by it. For instance, at the end of the novel Jove and Stella find themselves lost at sea — an event that in the context of the characters' inability to know themselves can be interpreted as symbolizing the basic condition of human existence — and the latter's sense of stable identity is consequently compromised. 'The point that I am', she notes, 'the definite bounded thing in time, is beginning to break up. I am dispersing myself through my known past and my unknown future. The present is without meaning' (pp. 185–86). Again pointing to the paradoxical quantum logic of both/and through the juxtaposition of opposite concepts such as *known* and *unknown*, the novel uses the idea of a divided self as a means of describing the 'postmodern sense of the instability and perpetual flux of the universe' (Grice and Woods, 'Grand (Dis)Unified Theories?', p. 118) that the characters of Alice and Stella embody.

The impact of time on identity is also emphasized through the paradoxical idea that while the past affects the present and the future of the characters, their present and future seem to equally affect their past. For instance, Stella's description of her own sense of identity reflects this. 'I can't go back into the past and change it', she notes, 'but I have noticed that the future changes the past. What I call the past is my memory of it and my memory is conditioned by who I am now. Who I will be' (p. 45). Although stating the rather self-evident idea that one's past changes as one's memory of it changes, Stella's remark nevertheless foregrounds the interdependent — indeed, antimetabolic — nature of the three categories of time: just as the past is created by the present and the future, so the present and the future determine the meaning of our past for us. In this sense, her ideas echo Zohar's use of antimetabole in her notion of memory as the crucial link between the individual's past and present selves.

Although Alice and Stella thus seem to inhabit a world of instability, the novel suggests that there are balancing factors against the sense of almost unmanageable fluidity. For instance, as in Winterson's stories in general, narratives and the act of narration are means of introducing stability into a world of constant change. Alice, who considers herself 'a fool' (p. 24) because of her attempt to understand the elusive universe, tries to find solidity in the narratives of science. 'I know I am a fool,' she confesses, 'trying to make connections out of scraps but how else is there to proceed? The fragmentariness of life makes coherence suspect but to babble is a different kind of treachery' (p. 24). In a world of continuous change, she realizes that telling stories fulfils the vital function of making sense of it: 'Some story we must have. Stray words on a crumpled paper. A weak signal into the outer space of each other' (p. 25). This suggests that her own grand narrative of esoteric thought mixed with physics mainly functions to satisfy her need for stability and order amidst change. Storytelling hence emerges as a survival strategy against the anxiety caused by the realization that reality might resist our attempts of making it into a neat story. 'Walk with me', Winterson encourages her readers through Alice, 'Hand in hand through the nightmare of narrative. Need to tell a story when no story can be told. Walk the level reassuring floor towards the open trapdoor' (p. 157).

In addition to narratives and storytelling, the novel explores relationships as something that transforms the anxiety produced by ceaseless change into a sense of meaningfulness. Although she seems unable to grasp the nature of the relationship between her self and the world, Alice nevertheless maintains that the new physics has shown how 'our place in the universe and the place of the universe in us […] is proving to be one of active relationship' (pp. 97–98). Hence, like Capra, Zukav, and Zohar, she uses an antimetabolic formulation to register the shift from the Newtonian worldview, which regards objects as separate entities, to the view held by contemporary physics (‘The hard-hat bull-nose building blocks of matter, manipulated by classical physics, now have to be returned as an infinite web of relationships’ (p. 161)).

This view is evident in the way the novel creates a parallel between the seemingly opposing epistemologies of the new physics and the cabbala, the tradition of Jewish mysticism. The two are brought together through the poet Stella, for whom there is no distinction between different types of knowledge:

> In the Torah, the Hebrew ‘to know’, often used in a sexual context, is not about facts but about connections. Knowledge, not as accumulation but as charge and discharge. A release of energy from one site to another. Instead of a hoard of certainties, bug-collected, to make me feel secure, I can give up taxonomy and invite myself to the dance: the patterns, rhythms, multiplicities, paradoxes, shifts, currents, cross-currents, irregularities, irrationalities, geniuses, joints, pivots, worked over time, and through time, to find the lines of thought that still transmit.
>
> The facts cut me off. The clean boxes of history, geography, science, art. What is the separateness of things when the current that flows each to each is live? It is the livingness I want. Not mummification. (pp. 82–83)

In contrast to Alice’s anxious relationship to reality and Jove’s rational, detached attitude (‘There is nothing mystical about the universe. There are things we cannot explain yet. That is all’ (p. 191)), Stella celebrates the strange and dynamic fluidity of the world around her, indicated by the synoeciosis-like juxtaposition of seemingly opposite concepts such as *charge* and *discharge*. Like that of Capra, Zukav, and Zohar, her worldview emphasizes interaction and blending between categories thought separate from each other, therefore clashing with the views of Jove, who wishes to ‘make a clear distinction between inner and outer’ (p. 191).

The idea that it might not be possible to separate the scientific from the mystical, or the rational from the irrational, emerges in the pivotal episode in which Stella and Jove get lost at sea in their yacht. Stella, living inside her subjective universe of cabbalistic correspondences, confronts the objectivity of the material world — literally — head on, as she hits her head and suffers concussion as a result. Jove in turn has something of a mystical experience, as he grows weak from hunger and thirst. In the isolation of the ocean, he notes, '"I think therefore I am" had no meaning anymore. Quite often I had the disagreeable sensation that I was being thought' (pp. 194–95), a remark indicating the breakdown of his rationalism. In a manner that is simultaneously gruesome and humorous, the rational Jove and mystic Stella are united as 'one flesh' (p. 196), as the former about to starve to death engages in an act of cannibalism by devouring the latter's buttock. (A similar link between the epistemologies of the new physics and mysticism is established, as it is revealed that Stella's father, also a student of cabbala, was in close correspondence with Heisenberg, recognizing 'in the paradoxes of Kabbalah […] the paradoxes of new physics' (p. 168).) This again reflects the reciprocal logic of antimetabole in Capra and Zukav, as science and mysticism move closer to each other.

The same kind of dynamic interplay that characterizes the relationships of the characters with the world is also evident in the novel's portrayal of interpersonal relationships. Alice and Stella encounter the possibility of transformation in their love for each other. In contrast to the insubstantial and ephemeral reality of contemporary physics, love appears to provide — at least temporarily — the sense of stability that especially Alice longs for: '*Cogito ergo sum* or is it *Amo ergo sum?*', she asks, 'I think therefore I am? I love therefore I am? What has defined me at the clearest point of my out-spread life has been my love for you. Not a raft or a lifebelt. A fix in the flux' (pp. 206–07). However, like individual identities, relationships in the novel seem to be fluid rather than stable. Following the analogy between the microscopic and the macroscopic, human relationships behave as subatomic particles do, thus suggesting the 'postmodern lexicon of slippage, fluidity and dynamism' (Grice and Woods, 'Grand (Dis)Unified Theories?', p. 117). Like the smallest building blocks of matter, Alice, Stella, and Jove are constantly engaged in paradoxical behaviour in regard to each other. 'I touch you', Alice notes of Jove, 'and you disappear. Always you escape me. The nearer I come to you the further off you seem. The more I know of you the more enigmatical you are' (p. 206). Just as Capra and Zukav with their use of synoeciosis and oxymoron in their portrayals of the paradoxical qualities of subatomic particles, then, Winterson depicts the relationships of her characters by juxtaposing seemingly opposite qualities that seek to become united through love.

Such fluidity and dynamism are also suggested by the way in which the relationships between the characters form an interconnected whole, thus resembling the network universe of Capra and Zukav. For instance, Alice describes her relationship to her father in terms of love that transcends the boundaries of culturally accepted behaviour: 'I loved my father incestuously. I would have coupled with him in a different morality' (p. 126). It is hinted that Alice's father, a shipping magnate from Liverpool, and Stella's mother may have had an affair when the former had gone to New York to be employed by a shipping company: recalling his family's history, Jove notes that his 'wife's mother had an affair with an Englishman brought over to run a shipping line' (p. 190), while Alice reveals she had discovered letters signed by Stella's mother in her father's room (p. 199). Suggestively, in Alice's mind the boundaries between herself and those close to her are blurred: 'I could not fully distinguish which was my father/myself, Stella/Uta, whether the distance we imagine separates one event from another had folded up' (p. 199). In this way, the logic governing relationships in Winterson's novel is similar to the one on which Zohar builds her theory of quantum relationships: drawing from the logic of both/and suggested by wave-particle duality, her portrayal pictures the individual as a compound of a subjective sense of I and the other.

Moreover, it is possible to observe how the notion of relationships as an overlap of identities is closely linked to the novel's sexual politics. Helen Grice and Tim Woods argue that Winterson's portrayal of the love triangle of Alice, Jove, and Stella is a means of questioning the male-female binary opposition: the fact that the lesbian relationship of Alice and Stella dominates the middle of the novel, while the heterosexual acts between Alice and Jove, and Stella and Jove, respectively, occur at the beginning and the end, shifts the narrative focus from the depiction of male-female relations to female-female ones, placing emphasis on sexual relations between members of the same sex rather than those of opposite sexes (pp. 123–24). Through Alice's gaze on Stella, Winterson refers to the Narcissus myth in order to foreground the fluidity of the boundaries of the lovers' selves:

> Her breasts as my breasts, her mouth as my mouth, were more than Narcissus hypnotised by his own likeness. Everybody knows how the story changes when he disturbs the water. I did disturb the water and the perfect picture broke. You see, I could have rested there beside her, […] a mirror confusion of bodies and sighs, undifferentiated, she in me, me in she and no longer exhausted by someone else's shape over mine. (p. 119)

By using synoeciosis (*her* and *my*) and antimetabole (*she in me, me in she*) in the manner of Zohar, Winterson portrays the individual as a composite of I and you, as the boundary between the self and the other becomes blurred. With Jove thus banished from the top of the triangle, Alice and Stella are no longer competitors for the love of the same man. (At the beginning of the novel Alice describes their *ménage à trois* through a comparison to Euclidian geometry: ‘the angles of a triangle add up to 180 degrees and parallel lines never meet. Everyone knows the score, and the women are held in tension, away from one another’ (p. 17).) In this way, the novel replaces the binary logic (man/woman) with the logic of oneness (woman/woman) — a characteristic evident in the questioning of fundamental binary oppositions by notable feminist theorists, such as Hélène Cixous and Luce Irigaray (Grice and Woods, ‘Grand (Dis)Unified Theories?’, p. 124).

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The microscopic also functions as a model for the macroscopic in the British novelist Ruth Brandon’s *The Uncertainty Principle*, which creates an analogy between scientific and human types of uncertainty. The story’s protagonist, Helen Spiro, a scriptwriter, and her scientist husband, Benny, have lost their daughter Laura years ago in a traffic accident. One day at a shopping centre, Helen sees a girl who physically resembles Laura and begins a search to discover the girl’s identity. The search eventually reveals not only the girl’s identity but also the double life Helen’s husband has led: the girl was fathered by Benny with a woman working for a shadowy research centre that studies the link between contemporary physics and paranormal phenomena called the Synchrony Institute. Thus, Brandon explores the relationship between science and religion, taking up the idea expressed forcefully in the work of writers such as Mary Midgley and Margaret Wertheim, who argue that science has become the religion of the twentieth century by providing answers to what are essentially metaphysical questions.[37]

The novel establishes a link between the subatomic world and the world of human affairs by suggesting that like particles, individuals possess hidden identities in addition to the observable ones — an idea also explored in Tom Stoppard's *Hapgood* and Michael Frayn's *Copenhagen*. Helen, for instance, is unaware of her husband's political activism in his native South Africa, his involvement with the Synchrony Institute, and his relationship to his former girlfriend. Benny in turn does not know that he is not the biological father of his son with Helen. Even Helen's best friend, Colette, whose friendship Helen has always thought as a 'constant thing',[38] becomes potentially untrustworthy because of her possible intimate involvement with Benny. 'Colette has suddenly changed roles', the narrator voices Helen's thoughts, 'What part is she playing now? Helen can't be certain' (p. 221). Moreover, other uncertainties plague Helen's mind: while Helen's workmate Patrick disappears without explanation, Patrick's son, Declan, disappears to spend time with Benny at the Synchrony Institute. Hence, the more Helen knows about the people in her life, the more she realizes how little she has known about them. Because of such gaps in knowledge, 'the unsaid, the unseen, the unperceived', Helen's world is becoming increasingly insubstantial: 'Nothing is solid, nothing is what it seems' (p. 134). By thus focusing on the idea that like the fundamentally dualistic subatomic particles, individuals

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[37] See especially Midgley's *Evolution as a Religion: Strange Hopes and Stranger Fears* (London: Methuen, 1985) and *Science as Salvation: A Modern Myth and Its Meaning* (London: Routledge, 1992) and Wertheim's *Pythagoras' Trousers: God, Physics, and the Gender Wars* (New York: W. W. Norton, 1995).

[38] Ruth Brandon, *The Uncertainty Principle* (London: Cape, 1996; London: Random House, 1997), p. 220. Further references to this book are given after quotations.

are dual personalities, the novel creates a link between knowledge and identity at the macroscopic level of human life. The notion that just as it is possible to observe only one aspect of a particle's behaviour at a time, so our knowledge of the lives of others is always bound to be partial reflects Zukav's antimetabolic formulation of the uncertainty principle: if we know one part of someone's personality, there is another part that remains hidden from us and vice versa.

The notion of individuals as particles of whom our knowledge is bound to be uncertain is given a scientific basis through the exposition of the theories of Stefan Kertes, the Synchrony Institute's leader, whose aim is 'to relate quantum physics to the real world' (p. 69), that is, to reconcile the features of the microscopic world with those of the macroscopic one. In Kertes's thinking the idea of both particles and human beings possessing dual identities is linked to the concept of parallel universes explored in the so-called many-worlds interpretation of quantum physics, which has been favoured by theoretical physicists such as Hugh Everett, who formulated the interpretation in 1957, and more recently, by David Deutsch.[39] This interpretation states that reality consists of an infinite number of parallel worlds (or universes) in which all possible outcomes of all possible decisions are actualized. Extending the metaphorical implications of this idea for life in the macroscopic world, *The Uncertainty Principle* suggests that its characters appear to occupy parallel worlds that are simultaneously partly visible to and partly hidden from the others. Just as there is 'an infinity of universes' containing 'every possibility' (p. 107)

[39] Everett explored this interpretation in his PhD thesis *The Theory of the Universal Wave Function*. Deutsch is a physicist who has popularized the many-worlds interpretation in books such as *The Fabric of Reality: The Science of Parallel Universes and Its Implications* (London: Penguin, 1998).

in the parallel worlds, so 'each possible position of a particle exists inside its own universe' (p. 108) in their microscopic counterparts.

The notion of characters occupying private worlds serves not only to emphasize the duality of identity but also to form a conceptual basis for the novel's exploration of the problem of free will. This is evident in Helen's constant pondering on the choices she has made during the course of her life. 'Benny […] always hated the notion of karma', Helen observes of her husband's attitude towards the question of free will,

> that vacant fatalism that threatened to consume them all during the sixties and seventies. That was one of the things that drew them together, the shared violent certainty that their lives were theirs to mould. You chose one thing, and then you chose another.
>
> But what of all those paths untaken, the possibilities unexplored? What happened to all those myriad Bennies and Helens, Patricks and Colettes, the ones who might have been? The ones whose paths diverged? Do they exist somewhere, as Benny later proclaimed? What are their worlds like? (pp. 21–22)

For Benny, the many-worlds interpretation offers scientific validation for the idea that individuals can choose among infinite futures, that they are in possession of complete freedom of will. In this sense, Benny's reasoning is a means of entertaining the possibility that although physically dead in this world, Laura might still be alive in another dimension.

Yet, in order to foreground the problems involved with such a view, the novel sets it against the concept of predetermination. The idea that the paths of our lives are determined in advance emerges, for instance, in a passage in which the narrator describes how the young Helen engages in conversation with a fellow applicant while waiting to be interviewed at Oxford University:

> Suppose Helen had liked Annabel Anderson. Suppose she had been impressed, had tried to impress in her turn. […]. What would have happened to *that* Helen? Would she have met

Benny Spiro — could he ever have entered her orbit? Or she his? Inconceivable. (p. 25; emphasis original)

Echoing Zohar's comparisons between particles and human beings, Brandon likens her characters to particles that traverse on their individual paths in the subatomic world. Just as it is impossible to make precise predictions concerning both the speed and location of the latter, so it seems to be difficult to say whether the former are bound for specific paths or not. In this way, although the passage does not reveal whether Helen's decision to eventually not to make Annabel's acquaintance was predetermined or not, the idea of a fixed future is mentioned as a speculative possibility that counterbalances Benny's idea of unlimited free will — the narrator's comment that it was a 'crucial moment' (p. 26) in Helen's life because she would not have met Colette had she introduced herself to Annabel leaves room for both kinds of views.

While leaving open the question about predetermination, the novel suggests that contrary to the new-age metaphysics of Benny and Kertes, people actually exercise less control over their futures than they might think. This is evident in the motif of synchronicity, a term that in the Jungian version of psychoanalysis — we learn that Kertes 'was a patient of Jung' (p. 114) — refers to a meaningful coincidence between events that are not causally related. For instance, Tim, the son of Helen and Benny, sees Benny's book *Immortality and the New Physics* only moments before Helen informs him of his father's death (p. 22); when Helen and Colette meet for the first time, they are carrying similar proof copies of Iris Murdoch's latest novel (p. 27); Kertes catches a big trout before he sees a book with fish symbols on its pages and is consequently freed from mental paralysis (pp. 114–15); Patrick meets the screenwriter of his upcoming film project when he accidentally tries to get into the latter's car (which is similar to Patrick's), and it is also revealed that both are headed for the same flight (p. 155); Benny finds his way to Synchrony Institute by following a small black dog that leads him to its gate, as the decision to follow the dog is motivated by its resemblance to Laura (pp. 187–88); Colette's call on Helen and Benny is preceded by two visits from a scarab, the image of which is found on Colette's wedding ring (pp. 192–93); and so forth. This would suggest that the lives of the novel's characters are indeed to a great extent predetermined, since the various meaningful coincidences indicate that they are meant to choose one particular path out of a myriad of possibilities.

In addition to this kind of archetypal predetermination, there is biological determinism that equally effectively seems to decide the futures of the characters. Describing Helen's relationship history, the narrator notes that attraction has a definite chemical basis: 'The mysterious ingredient which ensures that one thing will lead rapidly to another, shortly to be followed by total obsession, is a scent-carrying particle called a pheromone' (p. 52). This suggests that even though we might think we are exercising our free will when choosing prospective partners, the actual decisions have nothing to do with conscious judgment — the young Helen, for instance, is not destined to become a wife to a successful politician because the 'pheromones just aren't there' (p. 53).

In the end, the fact that the novel subjects its characters to these kinds of determinisms makes the idea of individuals freely choosing their futures appear untenable. On the one hand, Benny realizes this and states that

> time is just another dimension […]. Past, present and future are all there, just like up and down. And of course the same is true of all the parallel universes. And if the future is as real as the present and the past, then all the choices have already been made. (p. 180)

On the other hand, he claims it might be possible for humans to evade determinism by travelling mentally forwards and backwards in space-time, so that they could choose between different kinds of pasts and futures that exist simultaneously as parallel universes. Yet, rather than attempting to perform such science-fictionesque feats, Benny chooses the more mundane option of becoming father to Cherry, the girl Helen at first took for Laura, as he wants to ensure that ‘this time his daughter will have her chance, like all the other children’ (p. 253). Ironically, the fact that Cherry is born autistic prevents her from having her chance, and Benny’s sense of his own failure forces him to abandon her, which makes him commit suicide. This suggests that it is Benny’s hubristic desire to control the future for his selfish ends that eventually leads to such unpredictable consequences. Helen too learns that ‘life does not offer a rewind facility’ (p. 259), and she is freed from uncertainty, as she discovers ‘Laura’s’ real identity while at the same time accepting the ‘finality of death’ (p. 264). Indeed, in the final scene of the novel, Helen becomes the observer in a situation akin to the setting of Schrödinger’s famous *Gedankenexperiment* with a member of the feline species: she approaches the door of Benny’s study and opens it, thus symbolically causing the collapse of the alive-dead opposition — instead of opening a door to a parallel universe in which her husband is alive, she discovers an empty room in which Benny lives only in the past of her memories.

*   *   *

Like *The Uncertainty Principle*, Tom Stoppard’s play *Hapgood* builds a link between the microscopic and the macroscopic through an analogy drawn between the dual nature of particle behaviour and human identity. Its epigraph, taken from Richard Feynman's *The Character of the Physical Law* (1967), draws our attention to the crucial role wave-particle duality plays in quantum physics:

> We choose to examine a phenomenon which is impossible, *absolutely* impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality it contains the *only* mystery … Any other situation in quantum mechanics, it turns out, can always be explained by saying, 'You remember the case of the experiment with the two holes? It's the same thing'.[40]

Stoppard's comments on the play make it clear that he has found in wave-particle duality an apt metaphor for describing human identity. 'The trigger for the play', he explained in a television interview, 'was the notion that duality in particle physics had some sort of correspondence to duality in human personality.'[41] Like Brandon, then, Stoppard uses the analogy to introduce the idea that human identity is made up of elements that are often in conflict with each other and that behind a person's appearance there are selves hidden from the eyes of the observer.

Stoppard's examination of the dual nature of human personality takes place in the deceptive world of international espionage. The task of the play's protagonist, the British secret agent Elizabeth Hapgood, is to locate her assistant, Ridley, who is apparently a double agent working for the KGB, along with what apparently is Ridley's identical twin brother. The Soviets are interested in the research of the physicist Joseph Kerner, who has worked as a double agent for the British, but who may have gone over to the Soviet side,

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[40] Quoted in Tom Stoppard, *Arcadia*, in *Tom Stoppard: Plays Five* (London: Faber and Faber, 1993; 1999), pp. 1–137 (p. 483; emphases original). Further references to this play are given in parenthesis.

[41] Interview with Kate Kellaway, BBC TV, 13 March 1988.

thus becoming a triple agent. The situation is further complicated by the fact that Hapgood and Kerner have a son, Joe, whom the Soviets plan to kidnap if they do not get access to Kerner's classified information. In order to prevent her son from being kidnapped, Hapgood must assist the Soviets, thus becoming a double agent herself.

Along with wave-particle duality, the double agent functions as a metaphor for the self, allowing Stoppard to study the question of identity in terms of the logic of both/and rather than that of either/or. The analogy is introduced already in the opening scene of the play, in which Hapgood and the other British agents spy the meeting of the Ridley twins and two Soviet agents — who are also twins — at a public swimming pool. In terms of the issue of identity, the significant fact is that the twin going into a cubicle for the purpose of exchanging information is not the same twin that comes out of the same cubicle (see pp. 491–92). As such, the scene is modelled after the famous double-slit experiment in physics, to which Feynman refers in the play's epigraph: there are the observers (the British agents) and the observed (the Ridleys and the Soviets), and the identity of the latter changes while unobserved, suggesting that the observers are able to observe only one of the two aspects at a time.[42] Indeed, at the end of the first act, the analogy between particles and characters is made explicit through Kerner's musings on the nature of light. An electron, he explains to Hapgood,

is like a moth which was there a moment ago, it gains or loses a quantum of energy and it jumps, and at the moment of quantum jump it is like *two* moths, one to be here and one to

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[42] This experiment was first conducted at the beginning of the nineteenth by the English scientist Thomas Young, who used it to find out whether light consists of particles or waves moving across the ether. While Young's experiment indicated the latter, Einstein later proved that light is composed of photons, thus showing that particles such as photons behave in the manner of both particles and waves.

stop being there; an electron is like twins, each one unique, a unique twin. (p. 545; emphasis original)

By the passage's similes the play creates a comparison between the microscopic of the subatomic world and the macroscopic world of human affairs. Because particles have such a dual nature in the subatomic world, it follows that the observation of individuals in the macroscopic world is problematic. For instance, Merryweather, one of the British agents trailing Ridley and the Soviets, follows the wrong twin out because of the twin's paradoxical uniqueness-in-similarity (p. 493). Like the characters in Ruth Brandon's *The Uncertainty Principle*, then, the twins are like particles that are capable of exhibiting two different aspects of themselves, depending on the focus of observation.

As Stoppard's use of synoeciosis (*one to be here and one to stop being there*) and oxymoron (*a unique twin*) — which echoes the similar syntactic constructions in the writing of Capra and Zukav — indicates, the various twins can be understood as the contradictory qualities that individual characters simultaneously exhibit. Hapgood, for instance, plays the role of a tough, professional intelligence officer but is simultaneously a devoted and caring mother to her kidnapped son. From the viewpoint of international politics, she is Kerner's enemy but from the viewpoint of individual affairs, she is — as his lover — Kerner's ally. Similarly, Ridley betrays Hapgood but is clearly romantically attached to her, trying to rescue Hapgood's son, whom he thinks has been kidnapped by the Soviets ('I'll get her kid back for her but it's only personal' (p. 584)). (It is eventually revealed that the kidnapping was staged — without Hapgood's authorization — by the British side in order to lure Ridley into a trap (see p. 590).) Moreover, both Blair, Hapgood's senior officer, and Kerner seem to embody contradictory elements in their work.

'We're all doubles', Kerner explains to Blair, 'Even you. Your cover is Bachelor of Arts first class, with an amusing incomprehension of the sciences, but you insist on laboratory standards for reality, while I insist on its artfulness' (p. 572). Like Capra's yin-yang image of polar opposites containing the seeds of each other, then, Blair and Kerner represent personalities that antimetabolically embody each other's traits.

Grounding its model of the self on a scientific idea that appears to validate the logic of both/and, *Hapgood* undermines the notion of contradictory elements necessarily excluding each other. It is Kerner's exposition of the subatomic world that contains the key to understanding the identity of the characters in the play. Kerner makes a comment on Blair having been 'too long in the spy business' and consequently thinking that because 'everybody has no secret or one big secret, they are what they seem or they are the opposite' (p. 572), thus implying that Blair prefers to think in terms of the logic of either/or.[43] As an alternative to Blair's logic, however, the logic of both/and suggests that like their counterparts in the microscopic world, human beings embody contradictory qualities that do not cancel each other out, but which are revealed to observers when the observational focus shifts from one aspect to the other. For instance, in the fifth scene of the second act this idea is illustrated by a scene in which things — literally — look different in a different light. Being led on by the British team, Ridley is in a hotel room with somebody who he thinks is Hapgood's sister; in the cover of the dark evening setting, the sister becomes the Hapgood of Ridley's sexual fantasies, 'Hapgood without the brains or the taste' (p. 585). In contrast, Hapgood's tightly controlled daytime self is rather different

[43] See also William W. Demastes, *Theatre of Chaos: Beyond Absurdism, into Orderly Disorder* (Cambridge: Cambridge University Press, 1998), p. 45. Further references to this book are given in parenthesis.

from her night-time self, as can be observed, for instance, from her habit of substituting the more forceful curses with mild expressions such as ‘Oh, fiddle!’ (p. 542) when overcome by emotion. As Paul Delaney perceptively puts it, Hapgood’s plan of deceiving Ridley by playing the role of a non-existent sister ‘ultimately reveals to Hapgood not so much Ridley’s duplicity as her own duality’.[44]

Kerner, as I noted above, is also an embodiment of the idea that the individual self is more a both-and rather than an either-or affair. Reflecting the idea that in the subatomic world knowledge is probabilistic rather than certain, it is never entirely clear whether he has become a triple agent or not. On the one hand, Kerner’s confession that he is an information source for the Soviets is a part of the plan to catch Ridley, while on the other hand, the dialogue between Blair and Kerner in the third scene of the second act suggests that he did really deliver information to the Soviets. Stoppard leaves the truth of the matter open, thus merely foregrounding the idea that individuals consist of multiple selves that may be simultaneously engaged in contradictory activities. In the same way, the end of the play does not reveal whether Kerner decides to stay with Hapgood or not. He says goodbye to her at Joe’s rugby game and is about to take his leave but nevertheless turns back to watch the game (p. 593). It is, however, implied that even Kerner himself cannot answer these questions: regarding his status as an agent, he explains to Hapgood that ‘Paul thinks I was triple, but I was definitely not, I was past that, quadruple at least, maybe quintuple’ (p. 592). Hence, the play suggests that because of the self’s fundamental duality, uncertainty characterizes our perceptions of not only others but also ourselves — a metaphysical idea

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[44] Paul Delaney, *Tom Stoppard: The Moral Vision of the Major Plays* (London: Macmillan, 1990), p. 136. Further references to this book are given in parenthesis.

drawn from quantum physics that is also explored at length in Michael Frayn's *Copenhagen*.

In addition to Kerner, it is Ridley who along with his twin exemplifies the notion of the self as a both-and construction (Demastes, p. 46). Unlike Blair, he cannot separate his professional self from the private one, allowing himself to entertain the possibility of an intimate relationship with Hapgood. In the end, however, it becomes clear that he is unable to integrate the two sides of his self in the way Kerner does: while the selves of the latter eventually fuse into a unified whole as a result of realizing that not all his roles are mutually exclusive, the former remains fundamentally divided until the end of the play (Demastes, p. 46). As he considers the option of freeing Hapgood's son from the hands of the Russians, Ridley is still thinking in terms of the logic of either/or: 'I'll get her kid back for her but it's only personal. If she's set me up I'll kill her' (p. 584). In other words, instead of trying to act as both an intimate friend and agent, he thinks in terms of two mutually exclusive options, choosing the latter alternative after he realizes that he has been set up by Blair and Hapgood — Ridley's failure to carry out his plans is thus suggestive of his inability to choose two possibilities instead of one (see Demastes, pp. 47, 50).

What the logic of both/and suggests, then, is that the play shows the individual self to be a concept that is as evasive as the identity of particles. This, as Paul Delaney correctly points out, is evident in the names characters use of each other. For instance, Hapgood is 'Mother' to those under her command, 'Mum' to her son, 'Mrs Hapgood' to society, 'Elizabeth' to Blair, and 'Yelizaveta' and 'Lilya' to Kerner (Delaney, pp. 132–33). Moreover, she refers to herself as 'Betty' when playing the role of her twin sister, Mrs Celia Newton; 'Betty' in turn is referred to by Ridley as 'Auntie' (Delaney, p. 133).

Similarly, Kerner is 'Joe' to Hapgood in two simultaneous senses: he is 'Joe' to her in affectionate terms but also 'one of [Hapgood's] Joes' (p. 542) in the sense that Kerner was employed as a double agent, a 'joe', by Hapgood. Hence, like particles whose aspects can only be observed one at a time, Hapgood and Kerner play different roles depending on the context in which they are situated.

Finally, as with Stoppard's other plays, it should be noted that the intellectual content of *Hapgood* cannot be separated from what are essentially questions of morality and values. This, however, is not to say that the play derives its values from quantum physics. Instead, the ambiguous nature of the individual self, to which the wave-particle duality functions as a metaphor, leads to a questioning of moral certainties (see also Delaney, p. 138). In a world of constantly shifting, multiple identities, the play thus asks whether there can be a solid, universal foundation for human values or not.

Like the characters of Alice and Stella in Winterson's *Gut Symmetries*, Hapgood and Kerner seem to indicate that this is indeed possible, as their love is a factor that transcends their ideological commitments. 'There is something terrible about love', Kerner notes to Blair, 'It uses up all one's moral judgement. Afterwards it is like returning to a system of values, or at least to the attempt' (p. 573). For Kerner, then, commitment to ideology matters less than commitment to individuals: as I observed above, it is suggested that he does betray the British government by leaking information to the Soviets, but he does not betray the individuals he is committed to (see also Delaney, p. 138). In contrast, as also noted above, we find out that it is Blair who puts the life of Hapgood's son in jeopardy by delivering him into Ridley's hands as a part of the plan to catch Ridley. Hence, for Blair, the value of individual life is overridden by national concerns, perhaps owing to the fact that he plays by the either-or rules of the spy game (‘We can’t afford to lose. It’s them or us, isn’t it?’ (p. 591)).

Hapgood in turn appears to recognize the truth of the idea that the logic of either/or may needlessly simplify one’s approach to reality. ‘Oh, the KGB! The opposition!’, she cries in exasperation at Blair’s way of thinking, ‘Paul we’re just keeping each other in business, we should send each other Christmas cards — oh, f-f-fuck it, Paul!’ (p. 591). Disillusioned by the world of spying, Hapgood eventually returns to the values she left behind for national interests: she has kept her involvement with Kerner a secret for the purpose of not revealing her identity to the Soviets but at the end of the play lets her personal commitment to Joe and Kerner override her commitment to the government. Indeed, in Hapgood’s decision it is possible to see a renouncement of the logic of either/or: as Paul Delaney observes, ‘Hapgood, who first thinks of herself as being the good spy counteracting the bad spies, eventually comes to the conclusion that the values implicit in spying are the same for both sides’ (p. 143). Hapgood and Kerner thus learn to make decisions between right and wrong, even though the situation in which they are made might make such an achievement appear impossible (Delaney, p. 148). In the end, then, *Hapgood* foregrounds the value of concrete acts of goodness in individual relationships over the rather abstract notion of goodness in competing ideologies, especially as the latter type merely functions to justify the use of individuals for political ends.

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As in *The Uncertainty Principle* and *Hapgood*, wave-particle duality functions as a model for the self in Michael Frayn's *Copenhagen*, which probes into the mind of the father of uncertainty, Werner Heisenberg. The historical setting of the play is based on one of the less well-documented events in the Second World War: a meeting between the German physicist Werner Heisenberg and his Danish colleague, the pioneer of quantum physics, Niels Bohr, in the German-occupied Copenhagen in 1941. As Frayn's detailed discussion of the meeting in the postscript makes clear, the play seeks to address the question of Heisenberg's motivation for visiting Bohr, a topic that has puzzled numerous historians and biographers over the years.[45] In addition, although the meeting constitutes the central event of the play, Frayn links its portrayal to other thematically relevant historical episodes, such as the development of the German and Allied nuclear research programmes, the deportation of Danish Jews in 1943, and various occurrences in the lives of the two physicists.

Given the scientific role of the play's protagonists, it should be noted that in addition to referring to the meeting place of Heisenberg and Bohr, the play's title is an obvious allusion to the Copenhagen interpretation of quantum physics, which I touched on in 2.1. Formulated by Bohr, Heisenberg, and the Austrian-born American physicist Wolfgang Pauli in 1927, this interpretation — which is still the orthodox interpretation of quantum physics — is based on three interlinked elements: the probabilistic interpretation of wave function, the wave-particle duality of subatomic matter, and the uncertainty principle — in other words, more or less the same scientific ideas that Winterson, Brandon, and Stoppard use in their treatment of human knowledge and identity. For Frayn too wave-particle

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[45] Michael Frayn, 'Postscript', in *Copenhagen* (see Frayn, below), pp. 95–132 (p. 95). Further references to this chapter are given in parenthesis.

duality and uncertainty are means of portraying the mysterious and elusive nature of human consciousness.[46] Like the three writers discussed above, then, he creates an analogy between nature and mind, the behaviour of particles and the constitution of the individual self, and suggests that there is a certain limit not only to what we can know about the nature and others but also to what we can know about ourselves.

The play's three protagonists are the ghosts of Bohr, Heisenberg, and Bohr's wife, Margrethe, who have gathered together to seek explanation for Heisenberg's visit, which continues to haunt their minds even after death. The persistent nature of the question is reflected in the distinctively circular structure of the two-act play: Heisenberg arrives at the Bohrs' house three times, each time initiating a cycle in which the characters attack the question from a different angle. The fact that Heisenberg, Bohr, and Margrethe do never seem to arrive at a final explanation suggests that it might be impossible to give an unambiguous answer, thus foregrounding the idea that like the subatomic world, history and consciousness are phenomena that resist human efforts of knowing them completely (even though the play at the same time voices Frayn's own tentative proposal for the solution for the mystery).

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[46] Frayn notes that Heisenberg's biographers have used uncertainty in a metaphorical sense in order to describe a major conflict in the physicist's life. For instance, David Cassidy's *Uncertainty: The Life and Science of Werner Heisenberg* (New York: W. H. Freeman, 1992) suggests that the kind of uncertainty that characterizes Heisenberg's person in the eyes of posterity stems from the numerous conflicting views on his wartime role in Germany (see 'Postscript', p. 97). Thomas Powers in turn echoes Cassidy in *Heisenberg's War: The Secret History of the German Bomb* (New York: Knopf, 1993), suggesting that Heisenberg's role in the German atomic programme 'introduces an element of irreducible uncertainty' (quoted in Frayn, 'Postscript', p. 98).

The beginning of *Copenhagen* explores these ideas through the memories of the characters. Bohr and Heisenberg compare memory to a 'curious sort of diary'[47] that obscures rather than reveals. 'You open the pages', Heisenberg says, 'and all the neat headings and tidy jottings dissolve around you' (p. 6). It is in this simple sense that memory is uncertain in the play, with the characters seeming to be unable to provide definite answers for the questions they raise. For instance, when Margrethe suggests that one of the reasons for Heisenberg's visit to Copenhagen might have been the need for forgiveness from Bohr, Heisenberg denies it only to accept it moments later: 'Absolution. […] Is that what I've come for? It's like trying to remember who was at that lunch [Bohr] gave me at the Institute. Around the table sit all the different explanations for everything I did' (p. 39). Bohr in his turn does not remember having told Heisenberg the things his friend claims he had. Moreover, the memories of Bohr and Heisenberg regarding the development of the Copenhagen interpretation differ from that of Margrethe: while the scientists remember having worked on it together, Margrethe corrects them by insisting that they arrived at the important insights individually (see pp. 61–63). By foregrounding the imprecise nature of human memory, the play points to the difficulty of writing objective history: because our sense of what happened is filtered through a collection of subjective memories, the events, like the histories of subatomic particles, appear as probabilities rather than certainties.

This view is evident in the way the play creates an analogy between observations conducted at two different levels: the microscopic level of subatomic particles and the macroscopic level of human consciousness. While trying to focus on events from their

[47] Michael Frayn, *Copenhagen* (London: Methuen, 1998; New York: Random House, 2000), p. 6. Further references to this play are given in parenthesis.

personal histories — Heisenberg opens the diary of memory, and his gaze causes its contents to scatter — Bohr and Heisenberg are like observers of the subatomic world whose observation instruments necessarily disturb the observed, thus leaving knowledge of it partial:

MARGRETHE	If it's Heisenberg at the centre of the universe, then the one bit of the universe that he can't see is Heisenberg.
HEISENBERG	So …
MARGRETHE	So it's no good asking him why he came to Copenhagen in 1941. He doesn't know!
HEISENBERG	I thought for a moment just then I caught a glimpse of it.
MARGRETHE	Then you turned to look.
HEISENBERG	And away it went. (p. 72)

Heisenberg visualizes the various explanations for his visit as faces that disappear when he tries to focus his attention on them (p. 77). Just as at the microscopic level, then, macroscopic forms of observation — thinking, remembering, and so forth — appear to disturb whatever it is that is being observed. The analogy thus suggests that the observer and the observed are also inextricably linked to each other in human consciousness. Interestingly, like Capra, Zukav, and Zohar, who often employ antimetaboles to link the microscopic and the macroscopic together, Margrethe notes this through her exemplary use of the figure: 'If you're doing something you have to concentrate on you can't also be thinking about doing it, and if you're thinking about doing it then you can't actually be doing it' (p. 72). Moreover, using the same linguistic construction, Bohr makes the same point when he compares Heisenberg's way of skiing to his way of doing science:

> At the speed you were going you were up against the uncertainty relationship. If you knew where you were when you were down you didn't know how fast you'd got there. If you knew how fast you'd been going you didn't know you were down. (p. 24)

Through conceptual reversals such as these, the play introduces the idea that we really do not know ourselves because there is so much happening in one's mind that eludes conscious thought. (Note that Margrethe's first line in the first quotation of the paragraph creates a similar sense of circularity through its use of epanalepsis, suggesting the crucial idea that because Heisenberg is simultaneously the observer and the observed, he will never come to know his own motives.)

Heisenberg's last appearance at the Bohrs' door also highlights this problem. Before Bohr comes to open the door, Heisenberg is aware of the reason for his visit because he has not yet focused his consciousness on it: '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' (p. 86). The irony of the situation is, of course, that now that he knows, he does not want to ask, while when he does ask, he does not know. In order to show the similarity between microscopic and macroscopic uncertainty of knowledge, the play makes a comparison between particles and the contents of human consciousness:

> 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. (p. 86)

The light coming from the house is symbolic not only of the attempt of Heisenberg's consciousness to focus on a particular thought but also of the moment photons hit the observed particles, causing their dispersal. Consequently, because the light of his consciousness scatters his thoughts every time he focuses on them, Heisenberg continues to come to the Bohrs' front door without getting any closer to what he thinks is the real reason for his visit.

Hence, perhaps it is not too far-fetched to argue that the kind of circularity that characterizes the structure of the play reflects the nature of Heisenberg's problem: a mind caught in a loop of two inextricable strands of thought. This is most clearly evident at the end of the second act, where the characters discuss Heisenberg's involvement in the building of the atom bomb. While Margrethe — voicing the view of Samuel Goudsmit, Heisenberg's colleague who portrayed him in an unfavourable light in his memoirs (see Frayn, 'Postscript', p. 106) — claims that the German physicist did not understand the difference between a uranium reactor and a bomb, Heisenberg defends himself by saying that he understood the difference but wanted to delay the project as much as possible (p. 80). Heisenberg says that for this reason he never made the calculation concerning the amount of uranium needed for the chain reaction, thus effectively terminating the project. Bohr, however, suggests that the reason for Heisenberg's failure to make the calculation may be found not in his unwillingness to support the German atomic programme but in the ambiguous and contradictory nature of human thought: Heisenberg did not make the calculation because he 'hadn't consciously realized there was a calculation to be made' (p. 89), as Bohr explains to him. Bohr's explanation voices Frayn's own solution to the problem, and it is interesting to note that Frayn uses antimetabole to describe the 'seamless circle' in Heisenberg's mind: 'he didn't try the calculation because he didn't think it was worth doing — he didn't think it was worth doing because he didn't try it' (p. 123) — as we saw above, the same grammatical form epitomizes the logic of uncertainty in

Margrethe's and Bohr's lines. In this way, then, Frayn again foregrounds the idea that human consciousness is fundamentally uncertain because it is incapable of focusing on itself and that for this reason we can never know all the motives and intentions behind our own actions.[48]

As the play insists that the light of consciousness and the dark of unconsciousness, the observer and the observed, exist simultaneously without cancelling each other out, it is evident that it models human identity on the basis of complementarity. On this view, the self is a fundamentally divided affair, with the two opposites forming the totality of the whole. Heisenberg's description of the process leading to the formulation of the uncertainty principle constitutes another example illustrating this kind of duality:

> I start to think about what you'd see, if you could train a telescope on me from the mountains of Norway. You'd see me by the street-lamps on the Blegdamsvej, then nothing as I vanished into the darkness, then another glimpse of me as I passed the lamp-post in front of the bandstand. (p. 66)

In this passage Heisenberg clearly compares himself to a particle under observation. The observer cannot trace the whole history of the route he takes on his walk because of the uncertainty inherent in every act of observation. Consequently, what we get is a probabilistic rather than an objective history of Heisenberg's walk, a 'series of glimpses' (p. 66) with 'no precise addresses' (p. 67), suggesting that while subjective interpretations

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[48] Here Frayn seems to follow the reasoning of Thomas Powers, who uses uncertainty as an apt image for describing the contradictory — or dual — nature of his subject's life during the Second World War: Powers claims that while actively engaged in German atomic research, Heisenberg was apparently hesitant of using his knowledge for potentially destructive ends. In order to explain the situation, Powers suggests that Heisenberg may not have been conscious of everything going on in his mind, as 'questions of motive and intention cannot be established more clearly than he was willing to state them' (quoted in Frayn, 'Postscript', p. 98). Thus, it may well be that his two roles were so inseparable that he could not resolve the tension between them.

may illuminate the different aspects of the self, its totality cannot be exhausted by a single explanation. *Copenhagen* thus reminds us of the fact that the individual self is always perceived from a certain angle, as different perspectives illuminate certain aspects of the observed while leaving others in the dark. Often, as in the case of Heisenberg himself, we get diametrically opposite accounts of events and persons that do not cancel each other out but testify to a need for a multifaceted view in which truth is the totality of complementary aspects — a view in accordance with the holistic positions of Capra and Zukav. Heisenberg's remark to Bohr shows that he recognizes this in himself: 'I'm your enemy; I'm also your friend. I'm a danger to mankind; I'm also your guest. I'm a particle; I'm also a wave' (p. 77). Hence, juxtaposing seemingly opposite concepts in the manner of Capra's and Zukav's use of synoeciosis, the play foregrounds the idea that depending on the angle from which he is observed, Heisenberg appears to play a variety of apparently contradictory roles.

As in Ruth Brandon's *The Uncertainty Principle*, the idea that individuals are to a large extent driven by motives not known to either themselves or others raises the question about freedom of will and the possibility of controlling one's actions. Bohr thinks that it is Heisenberg's unconscious that prevented him from realizing the necessity of the calculation. 'So, you bluffed yourself', he concludes, 'the way I did at poker with the straight I never had' (p. 86), thus suggesting that the motives behind our decisions are not necessarily conscious. In this light, it is not surprising that like Brandon's story, the play constantly foregrounds the motif of making choices. For instance, Heisenberg describes downhill skiing in terms of facing a series of crucial choices:

HEISENBERG Decisions make themselves when you're coming

	downhill at seventy kilometres an hour. Suddenly there's the edge of nothingness in front of you. Swerve left? Swerve right? Or think about it and die? In your head you swerve both ways …
MARGRETHE	Like that particle.
HEISENBERG	What particle?
MARGRETHE	The one that you said goes through two different slits at the same time. (p. 25)

Another example of making decisions is Heisenberg's story of meeting a young woman at a concert in which he plays the piano:

I look up from the piano to see if the others are ready to start the final presto. And in that instant I catch a glimpse of a young woman sitting at the side of the room. Just the briefest glimpse, but of course at once I've carried her off to Bayrischzell, we're engaged, we're married, etc — the usual hopeless romantic fantasies. Then off we go into the presto, and it's terrifyingly fast — so fast there's no time to be afraid. And suddenly everything in the world seems easy. We reach the end and I just carry on ski-ing [*sic*]. Get myself introduced to the young woman — see her home — and, yes, a week later I've carried her off to Bayrischzell — another week and we're engaged — three months and we're married. All on the sheer momentum of that presto! (p. 28)

Both passages foreground the idea that choices are made somewhere else than in the conscious part of the mind (in the first passage Heisenberg reacts automatically to danger while in the second one he focuses on the music) that in the end cannot but — perhaps uselessly — speculate on the motives of its unconscious partner, to which it does not have an access. More than anything, as Margrethe's simile for wave-particle duality in the first passage suggests, unconscious decisions, like events in the microscopic world, are mysteriously random from the viewpoint of the conscious mind.

In other words, such scenes do not leave much space for free will, if free will is understood as freedom to make conscious decisions. Indeed, Heisenberg on the one hand notes that the individual's trajectory is 'completely determined by your genes and the various physical forces acting on you' (p. 69). On the other hand, your trajectory is 'also completely determined by your own entirely inscrutable whims from one moment to the next' (p. 69). Between biological and psychological determinism, then, the conscious mind occupies the role of the eternal questioner who can only watch and wonder, not act.

In addition, given the historical context of the play, there is also a third form of determinism: the socio-political. Because of the war, the two physicists are placed in a situation in which it is very hard for individuals to make morally acceptable choices. Heisenberg, for instance, is torn between his duty as a human being and the duty as a German. On the one hand, stopping the German atomic research programme might prevent mass destruction. On the other hand, it might also facilitate the destruction of Germany were the Allied to succeed in building the bomb first. In the end, however, Heisenberg and Bohr are saved the moral responsibility of making the choice: while the former does not have to make the decision because his mind gets caught in the circle of circular reasoning, in the latter's case 'the decision had been taken long before' (p. 46) by other Allied physicists. Hence, rather than basing their decisions on moral grounds, the choices in the lives of Heisenberg and Bohr are made for them by factors outside their conscious control.

Heisenberg's long anecdote about the last days of the war at the end of the second act also foregrounds the idea that there is an element of uncontrollable randomness involved in moral decisions. On his way home during the last days of war in Europe, Heisenberg is stopped by an SS man who is about to shoot him as a deserter, but he survives the incident by offering the man a pack of Lucky Strikes (p. 92–93). We are not revealed the reason for the man's random act of kindness, as he could easily have taken the cigarettes and then shot Heisenberg — in the context of what has been said about Heisenberg's inability to discover his own motivations, we might make the educated guess that he too does not know. Placed at the end of the play, the scene therefore epitomizes what is perhaps the greatest irony in the worldview based on the Copenhagen interpretation of quantum physics: although as observers individuals occupy the symbolic centre of the universe, they are nevertheless incapable of ever completely knowing themselves.

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While in 2.2.1 we saw how Fritjof Capra, Gary Zukav, and Danah Zohar use figurative language in order to establish an analogy between the microscopic and the macroscopic, in this subchapter I discussed how literature approaches the same task. I observed that literature relies heavily on characterization as a means of linking the two: in terms of their traits and relationships, the characters of Winterson, Brandon, Stoppard, and Frayn behave like particles under observation. Whereas Winterson depicts the identities of her novel's protagonists as overlapping and mutable as the ones of the building blocks of matter, Brandon, Stoppard, and Frayn use wave-particle duality as a metaphor for the self, suggesting that our knowledge about both ourselves and others is as uncertain as our knowledge about the behaviour of subatomic particles.

In addition, these writers occasionally employ figurative language similar to that in the three popularizations. Winterson, for instance, uses antimetabole and synoeciosis in her portrayal of the relationship between the individual protagonists on the one hand, and the protagonists and the world on the other. Frayn too finds in these two figures an apt means of approaching the topics of knowledge and identity: he uses antimetabole to portray the relationship between the observer and the observed and synoeciosis to describe the contradictory traits of the self. Antimetabole and synoeciosis are also present — although in a more implicit manner — in Brandon’s and Stoppard’s representations of the new physics, where they underlie the depiction of the uncertainty principle’s implications for the two topics.

2.3 Experiencing Time

I began my exploration of the various intersections of popularized new physics and contemporary literature by discussing two important topics that they share: knowledge and identity. Let me now finish my discussion by considering a third shared topic: time. While the question of time has always occupied the minds of novelists, poets, and playwrights, discussion about its relevance for human life has also become an important topic in popular science writing. In other words, with the appearance of numerous popularizations focusing on the scientific understanding of time in the 1980s, the importance of science for our perception of time has become one of the central topics of the genre.[49] The author whose books on time and related issues are analysed below represents one of the most prolific and well-known writers on this topic: the English physicist Paul Davies. Mainly known as a popularizer of ideas in contemporary physics and cosmology, Davies has also explored the philosophical implications of the new physics, and in *God and the New Physics* he attempts to approach essentially religious and philosophical issues, such as the question of free will, through the theories of contemporary physics.[50] While my analysis mainly centres on *About Time*, a popular science book dealing with the question of why relativity theory fails to explain the human experience of time, I also discuss Davies's treatment of the subject in *God and the New Physics*, focusing on his discussion of the relationship between physical

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[49] In addition to the work of the writer discussed in this chapter, Paul Davies, see, for instance, Stephen Hawking's *A Brief History of Time* (London: Bantam Press, 1988) and *A Briefer History of Time* (London: Bantam Press, 2005).

[50] Like many of his colleagues, Davies has also put his writing talents to use in fiction — his science fiction novel, *Fireball*, was published in 1987.

time (the measurable time of physics) and subjective time (our consciousness of physical time), which he sees as 'the greatest outstanding riddle' (*About Time*, p. 283) concerning time. The literary text I read alongside Davies's books is Ian McEwan's *The Child in Time*, which approaches the same question through a story about a married couple's attempts to cope with the loss of their daughter.

2.3.1 Are Physical and Psychological Time Irreconcilable Opposites?

In *About Time* Davies examines the implications of relativity theory and quantum physics for our understanding of time. Rather than trying to answer what time is, he discusses the current controversy surrounding this elusive subject. Davies argues that relativity theory's explanation of time is unsatisfactory because it fails to take into account the human experience of time (p. 10). For this reason, he says, we should look for the missing pieces of time's puzzle in other areas of research in physics and cosmology, such as black holes, time travel, quantum effects, the big bang, the arrow of time, as well as the relationship between physical and psychological time (pp. 280–83). Davies uses the speculative answers provided by these areas as a means for exploring the metaphysics of time, focusing especially on the questions of free will and human identity. Time, he argues, 'is in some ways the most basic aspect of our experience of the world. After all, the very concept of selfhood hinges on the preservation of personal identity through time' (p. 16). Similarly, in *God and the New Physics*, which deals with the philosophical aspects of time in less detail than *About Time*, Davies states that 'it is only in the flowing river of time that we can perceive ourselves' (p. 127), suggesting that the human mind can be properly understood only when time is properly understood.

Davies approaches the relationship between physical and psychological time by analysing the familiar time is a river metaphor. He begins by explaining how relativity theory envisions the existence of the so-called block time: instead of flowing through a metaphorical river in logical succession, past, present, and future events are seen to exist simultaneously as frozen blocks in a four-dimensional space-time continuum (*About Time*, p. 253). This, Davies notes, has led scientists and philosophers to regard time as a mental construction, since the flow characteristic of the human experience of time supposedly originates in the brain rather than in the world of matter (*About Time*, p. 253). For this reason, psychological time may appear as an illusory phenomenon that the human mind imposes on reality.

In contrast, everyday experience suggests that time has an inherently dynamic quality, as it seems to flow 'as a river flows past a bankside observer' (*The New Physics*, p. 127). Davies argues that the root of the conflict can be found in a paradox that characterizes molecular interaction at the atomic level: while molecular collisions are totally reversible — time flows symmetrically towards the future as well as towards the past — they nevertheless give rise to processes that are completely irreversible, such as a perfume transforming from liquid to scent in the air (*The New Physics*, p. 126). Hence, while time symmetry is a common phenomenon in the universe, our everyday experience of the world speaks for time asymmetry.

Although this state of affairs seems to suggest an irreconcilable dichotomy, Davies maintains that there is no real conflict involved because time symmetry and time asymmetry concern 'simply two different levels of description' (*The New Physics*, p. 127) that cannot be reduced to the properties of each other.[51] Hence, the fact that we see time as a flowing river indicates that the flow suggested by the metaphor is a mental phenomenon and as such needs to be separated from another common metaphor: the arrow of time. He defines the difference between these concepts as follows:

> Many people muddle the flow of time with the arrow of time. This is understandable, given the metaphor. Arrows, after all, fly — as time is supposed to do. But arrows are also employed as static pointers, such as a compass to indicate north, or a weather wane to show the direction of wind. It is in the latter sense that arrows are used in connection with time. (*About Time*, p. 256)

In this way, Davies argues that time asymmetry — time flows irreversibly from the past towards the future — does not depend on the flow or flux of time. In order to support this argument, he uses an analogy that contrasts time asymmetry and a film showing the breaking of an egg, an obvious example of an irreversible process. If we were to divide the film into separate frames and then rearrange their order, we would not experience any difficulty in putting the frames in correct chronological order because we would be able to

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[51] In the last chapter of *God and the New Physics*, Davies quotes the famous American physicist Richard Feynman to summarize the implications of this kind of holistic attitude towards scientific explanation: 'Which end is nearer to God; if I may use a religious metaphor. Beauty or hope, or the fundamental laws? I think that the right way, of course, is to say that what we have to look at is the whole structural interconnection of the thing; and that all the sciences, and not just the sciences but all the efforts of intellectual kinds, are an endeavour to see the connections of the hierarchies, to connect beauty to history, to connect history to man's psychology, man's psychology to the working of the brain, the brain to the neural impulse, the neural impulse to chemistry, and so forth, up and down, both ways. And today we cannot, and it is no use making believe that we can, draw carefully a line all the way from one end of this thing to the other, because we have only just begun to see that there is this relative hierarchy. And I do not think either end is nearer to God' (quoted in Davies, *The New Physics*, p. 225). As can be seen in this long passage, Feynman uses quite an exemplary gradatio in order to epitomize his argument that abstract concepts such as beauty cannot be reduced to down to the fundamental laws governing matter more than fundamental laws can be explained through abstract concepts. In the same way, Davies's argument concerning the relationship between physical and psychological time maintains that the two cannot be used to explain each other, as they belong to different levels in the structural hierarchy of temporal phenomena.

determine the direction of time's arrow without necessarily watching the film again (*About Time*, p. 257). For this reason, Davies suggests, time's arrow 'is a structural property of the set of the frames' (*About Time*, p. 257) — in other words, the arrow is there regardless whether the event is represented as a set of separate frames or as a continuous, flowing film.

However, as noted above, rather than wanting to argue that one of the two types of time is an illusion, Davies aims to build a bridge between the seemingly contradictory views. He first notes the sense of contradiction in himself as follows:

> As a physicist, I am well aware how much intuition can lead us astray. As I remarked earlier, intuition suggests that the sun moves around the Earth. Yet, as a human being, I find it impossible to relinquish the sensation of a flowing time and a moving present moment. It is something so basic to my experience of the world that I am repelled by the claim that it is only an illusion or misperception. (*About Time*, p. 275)

For Davies, the quest of finding the missing link between physical and psychological time is essentially the same as the age-old attempt of reconciling the gap between the concepts of being and becoming. He points out that the English astronomer A. S. Eddington saw a link between the two types of time and quotes him as follows: 'If I grasp the notion of existence because I myself exist, I grasp the notion of becoming because I myself become. It is the innermost Ego of all which *is* and *becomes*' (quoted in Davies, *About Time*, p. 97; emphases original). Note that in terms of its linguistic formulation, Eddington's statement contains certain elements that give it its distinct rhetorical force. Firstly, both clauses of the first sentence use parallel syntax that creates a sense of balance between the terms *existence* and *becoming*. Secondly, in the second sentence this sense of balance becomes stronger because Eddington subjects the terms to a third, all-inclusive term (*the innermost Ego*), thus basing the relationship on complementarity rather than exclusion. Thirdly, Eddington repeats the main concepts by using their different forms, as the nouns *existence* and *becoming*, and the verbs *exist* and *become* carry the rhetorical force of the argument; in this last sense Eddington's formulation corresponds to the use of a figure of speech called polyptoton, the repetition of a word in its different grammatical forms. As a result of such linguistic manoeuvres, being and becoming, the time of physics and the subjective time of human experience, are given an equal status as the essential building blocks of subjectivity.

Obviously inspired by Eddington's efforts of reconciling the two types of time, Davies speculates on the possibility of '*postmodern* physics' (*About Time*, p. 277; emphasis original) that would help us understand their relationship better. He suggests that some of its branches, such as chaos theory, might bring us closer to a scientifically verifiable reconciliation of the two types of time. With their mixture of both orderly and disorderly elements, Davies argues, chaotic systems, such as the human brain, are fundamentally indeterministic and as such correspond to static-dynamic dialectic of frozen and flowing kinds of time (*About Time*, p. 277). In a different way, he claims, quantum physics too could create a link between physical and subjective time: the idea that the act of observation causes the collapse of the wave function (the particle is seen either as a wave or a particle) — which is by no means a generally accepted view of how potentiality becomes actuality in quantum physics, but Davies seems to subscribe to it — links consciousness to physical processes by suggesting that the two are inseparable from each other (*About Time*, pp. 277–78). For Davies, then, such physics could give us a reconciliatory scientific theory that recognizes the reality of both physical and subjective kinds of time without dismissing one at the expense of the other. This, he concludes, would have far-reaching consequences for our understanding of nothing less than ‘the nature of the human self’ (*About Time*, p. 278).

From the viewpoint of Davies’s rhetoric, we could therefore say that *postmodern physics* functions as an all-inclusive term to which both scientific and human time are subjected. As such, the term itself has a reconciliatory function in Davies’s argument, even though he does not seek to provide conclusive proof for the hypothesis — as noted above, *the innermost Ego* has a similar function, as Eddington uses it to undo the opposition between the apparently opposite concepts of being and becoming.

For Davies, the relationship between the two types of time is closely connected to another problematic relationship: the one between free will and determinism. He begins the discussion by noting that the two revolutionary building blocks of the new physics seem give rise to diametrically opposite views on the issue. While relativity with its block time suggests that the future ‘in some sense already exists’, thus implying deep-seated determinism, quantum physics, with the crucial role it gives to the observer, ‘appears to offer human beings a unique ability to influence the structure of the physical universe’ (*The New Physics*, p. 135), a view that would speak for free will. As in the case of the opposition of physical and psychological time, however, Davies’s intention is to show that the opposition is merely apparent. Although relativity theory’s four-dimensional model of the universe also includes future events, it does not say anything about the causal links between past, present, and future events (*The New Physics*, p. 137). In this sense, then, relativity, like quantum physics, describes a universe in which the future is indeterminate (*The New Physics*, p. 137).

Like postmodern physics, the concept of indeterminacy is here used as a term to which an opposition is subjected. It hence seeks to build a bridge between relativity theory and quantum physics by showing that both allow the idea of an indeterminate future.

Davies is nevertheless sceptical about whether indeterminism guarantees that individuals truly possess a free will. 'Indeed,' he writes, 'the determinist would argue that free will is only possible in a *deterministic universe*' (*The New Physics*, p. 137; emphasis original). Following this logic, we could not say that the inhabitants of an indeterministic universe would have freedom of will because there are no causal relationships between events (*The New Physics*, p. 137). A completely deterministic universe, on the other hand, would effectively forbid free will because even though people might be able to make choices, the motivations behind them would be determined beforehand. Once again, Davies uses an analogy to illustrate his argumentation:

> When you choose to drink tea rather than coffee, the decision is due to environmental influences (such as, tea is cheaper), physiological factors (coffee is a stronger stimulant), cultural dispositions (tea is a traditional drink), and so on. Determinism asserts that every decision — every whim — is determined in advance. If that is so, however free you may feel to choose tea or coffee, in reality your choice was destined from the moment you were born — even before. (*The New Physics*, pp. 138–39)

Hence, neither indeterminism nor determinism seems to validate free will, and after discussing other similar arguments, he has to admit that the philosophical problems concerning the relationship between determinism and free will 'seem insurmountable' (*The New Physics*, p. 143). For Davies, then, the new physics does not in itself offer a final solution to this problem, as both relativity theory and quantum physics neither wholly affirm nor wholly deny free will. What his argument does, however, is that it makes the opposition between relativity and quantum physics appear less sharp in regard to the question of free will; this constitutes a reconciliatory attempt similar to his reconfiguration of the opposition between physical and psychological time.

2.3.2 Reconciling the Temporal with the Timeless

The problematic relationship between the time described by physics and the time of human experience is also explored in Ian McEwan's *The Child in Time*. The novel tells the story of Stephen Lewis, a former author of children's books, whose three-year-old daughter, Kate, has apparently been abducted. Stephen now works for the governmental 'Sub-committee on Reading and Writing',[52] which studies children's linguistic learning abilities. Because of his loss, Stephen has become alienated from his wife, work, and society. However, after a series of deeply meaningful experiences, he gradually emerges from the depths of his personal trial with a greater understanding of himself and is eventually able to overcome his estrangement. The relevance of *The Child in Time* to the discussion on the representation of time in popular science writing and literature derives from the fact that McEwan studies the protagonist's transformation primarily as an experience of different types of time: by its numerous references to both relativity theory and quantum physics, the novel explicitly sets the temporal against the timeless as a means of portraying the emergence of Stephen's new self. In this way, it uses certain ideas from the new physics in order to emphasize the

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[52] Ian McEwan, *The Child in Time* (London: Random House, 1987; 2001), p. 4. Further references to this book are given in parenthesis.

meaningfulness of the subjective experience of time in contrast to the everyday experience of time as a river-like flow of events from the past towards the future. Viewed in a larger theoretical context, this implies that by turning to the new physics for conceptual inspiration, McEwan has sought to validate the same kind of view of the temporal experience that is evident in Romanticism and strands of Modernism such as that of T. S. Eliot, in which the experience of the timeless gives rise to a meaningful sense of individuality in the mechanistic and deterministic Newtonian universe.[53] As suggested but not completely affirmed by Paul Davies, then, the ideas of the new physics appear to promise reconciliation between the opposites of complete determinism and indeterminism, as the protagonist of the novel is able to renew his relationship to the world through his experience of the timeless.

The beginning of *The Child in Time* focuses on Stephen's experience of time after his daughter's disappearance. As he mourns for his daughter, Stephen's sense of meaning is dependent on a fantasy that he keeps projecting on the future. 'Kate's growing up', the narrator notes, 'had become the essence of time itself. […]. Without the fantasy of her continued existence he was lost, time would stop' (p. 2). In other words, because he constantly dwells on the past while having unrealistic expectations of the future, Stephen's main problem is that he has ceased to live in the present moment, which he experiences as 'empty time, dry of meaning or purpose' (p. 30). This is foregrounded, for instance, by the fact that the portrayal of the meeting of the subcommittee at the beginning of the novel is

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[53] See also Marc Delrez, 'Escape into Innocence: Ian McEwan and the Nightmare of History', *ARIEL: A Review of International English Literature*, 26.2 (1995), 7–23; Paul Edwards, 'Time, Romanticism, Modernism and Moderation in Ian McEwan's *The Child in Time*', *English: The Journal of the English Association*, 44.178 (1995), 41–55.

constantly interrupted by Stephen's memories of his schooldays and the day of Kate's disappearance. By thus disrupting the linearity of the narrative, McEwan suggests that Stephen is unwilling to accept the fact that time flows on, increasing the distance between him and Kate. At same time, however, Stephen realizes that there is no returning to the lost past of 'uninterrupted time' preceding Kate's abduction, for the forward motion of time 'monomanically forbids second chances' (p. 8). From this follows that Stephen feels unable to break free from the bleak determinism of 'the commonplace of irreversible time' (p. 100): his future seems to be determined by Kate's loss, with no chance of changing its direction. As in Davies's analogy of an observer standing on the bank of a river, then, here mind acutely experiences time as asymmetry between the past and the future.

Yet, having thus outlined Stephen's problem of helplessly flowing with the river of time, the novel turns to T. S. Eliot's *Four Quartets* (1943) for a possible solution. Eliot, who is both alluded to and explicitly quoted in McEwan's novel, ponders on the meaning of time from human perspective at the beginning of 'Burnt Norton' as follows:

> Time present and time past
> Are both perhaps present in time future,
> And time future contained in time past.
> If all time is eternally present
> All time is unredeemable.
> What might have been is an abstraction
> Remaining a perpetual possibility
> Only in a world of speculation.
> What might have been and what has been
> Point to one end, which is always present. (I, 1–10)[54]

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[54] T. S. Eliot, 'Burnt Norton', in *Collected Poems: 1909–1962* (London: Faber and Faber, 1963; 1986), pp. 189–95.

Note how the antimetabole in first three lines creates a sense of time symmetry, as the past, the present, and the future seem to exist simultaneously. Unlike the time is a river metaphor that has them occurring in sequence, this formulation suggests that the three intersect each other in the present moment of consciousness. In a similar fashion, in the fifth part of 'The Dry Salvages' the speaker of the poem declares that 'men's curiosity searches past and future | And clings to that dimension. But to apprehend | The point of intersection of the timeless | With time, is an occupation for the saint —' (V, 17–20).[55] Together with the lines quoted above they express a — if not the — major paradox in the poems of *The Four Quartets*: although human consciousness is characterized by the flux of memories and fantasies, it is occasionally able to catch a glimpse of the realm of the timeless. That is, the otherwise meaningless unredeemable time can momentarily be filled with meaning, as certain types of religious experience suggest — significantly enough we discover that Julie, Stephen's wife, who has gone into a countryside retreat to deal with her sorrow, spends her time reading 'mystical or sacred texts — St John of the Cross, Blake's longer poems, Lao-tzu' (p. 49).

Accordingly, as Stephen gradually begins to emerge from his condition, the novel introduces more narrative interruptions as a means of exploring the idea that in addition to the irreversible, common-sense time, there exists other types of time. For instance, he gets into a traffic accident in which his perception of time becomes altered: instead of experiencing time passing at normal speed, he senses that 'the rapidity of events [during the accident] was accommodated by the slowing of time' (p. 91). In this state Stephen

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[55] T. S. Eliot, 'The Dry Salvages', in *Collected Poems: 1909–1962* (see Eliot, above), pp. 205–13.

experiences ‘a sense of a new beginning’ (p. 91) that, as we later learn, signals a positive turn in his life. Later he discusses the accident with his friend, the physicist Thelma Darke, who is the wife of his close friend and publisher, Charles Darke. Thelma, who has written her thesis on ‘the nature of time’ (p. 27), explains to Stephen that ‘the common-sense, everyday version of [time] as linear, regular, absolute, marching from left to right, from the past through the present to the future, is either nonsense or a tiny fraction of the truth’ (p. 116), thus criticizing the metaphor that likens time to a flowing river. Indeed, the novel appears to validate Thelma’s thesis by making him experience a vision of a fresh start with Julie during the accident, thus suggesting a collapse of strict boundaries between the present and the future.

Similarly, the connection between an experience of timelessness and a meaningful vision of future is evident in the story of the first encounter of Stephen’s mother with her future husband, Douglas: she meets him in the clock department of a department store, where he has come to claim refund for a stopped wristwatch (p. 169). In the context of the novel’s exploration of the relationship between the temporal and the timeless, the broken watch can be seen as a symbol of those deeply meaningful moments during which time seems to stand still, pointing to the eventual union of Stephen’s parents.

The story about Stephen’s parents is linked to an episode in which Stephen visits his wife’s countryside retreat. While approaching Julie’s cottage, his consciousness becomes completely focused on the surroundings. ‘He set off,’ the narrator notes, ‘and within minutes found satisfaction in this new landscape. He was marching across a void. All sense of progress, and therefore, all sense of time, disappeared’ (p. 48). Moments later Stephen heads for a pub called The Bell to seek shelter from the rain and discovers that he has entered a time before his birth: through the pub's window he sees his future parents, who seem to be discussing the possibility of abortion (pp. 55–56). Hence, by again portraying an event that suggests a collapse of the boundaries between the past, the present, and the future — Stephen's present consciousness encounters a vision of a meaningful event in his past that in turn concerns his future — the novel foregrounds the significance of the non-linear experience of time: it is only after Stephen sees them at The Bell that he realizes how his own life is inextricably tied to the life of his parents. 'He understood', the narrator notes, 'that his experience there had not only been reciprocal with his parents', it had been a continuation, a kind of repetition [through which] all the sorrow, all the empty waiting had been enclosed within meaningful time, within the richest unfolding conceivable' (p. 213). McEwan thus attributes a specifically cyclical nature to time, suggesting that the reality behind the illusion of one-way time unfolds as meaningful, repetitive patterns.

In spite of such episodes, however, the novel remains somewhat ambiguous about fully grounding its ontology on Thelma's explanation. On the one hand, Stephen's vision of Douglas and Clare at The Bell might be due to exhaustion from a long walk in the rain. On the other hand, since Stephen's mother later verifies the accuracy of his vision, the reader may be inclined to prefer Thelma's speculative remarks about parallel universes and the possibility of 'backward movement in time' (p. 116). Hence, although the novel's scientific ideas might influence one's interpretation to a certain extent, they do it without undermining the dominating sense of realism.[56] In this respect, *The Child in Time* emphasizes the reality of subjective experience over authoritative explanations such as

[56] See also Delrez, pp. 7–23 (pp. 11, 14).

those offered by science. 'You don't need physics', as Thelma remarks to the baffled Stephen, 'to explain what happened to you. Niels Bohr was probably right all along when he said that scientists should have nothing to do with reality. Their business is to construct models which account for their observations' (p. 118). Her words not only foreground the difference between scientific and subjective time but also point to Davies's notion that because the two belong to different levels of description, they should be regarded as complementary rather than opposite accounts.

Regardless of how we choose to explain Stephen's experiences, it is clear from the above examples that *The Child in Time* approaches the individual consciousness in terms that are quite distinctively Romantic in their insistence on portraying the mind as an escape route from the external world. This is evident especially in the conspicuous motif of making choices, through which the novel links the act of turning inward to the experience of timelessness. An event that clearly epitomizes the idea of the flux of consciousness giving way to single-minded concentration is Stephen's visit to Charles Darke in the countryside. After being forced to retire from a high position in the government, Charles, age forty-nine, has regressed into child-like existence: wearing old-fashioned schoolboy clothes, he spends his time in a tree house in schoolboy activities. Stephen agrees to climb to the tree house with Charles, and unexpectedly experiences something akin to an epiphany. 'It occurred to him fleetingly', the narrator observes, 'that he was engrossed, fully in the moment. Quite simply, if he allowed another thought to distract him he would fall out of the tree' (p. 108). Indeed, as he continues to recover, Stephen realizes that he must liberate himself from the tyranny of time by intensely focusing on the present moment; he consequently takes up activities such as learning classical Arabic and tennis in order to still his consciousness (pp. 156–57). (Julie also uses a similar strategy in order to overcome anxiousness: she practises demanding pieces on her violin for the sole purpose of stopping herself from thinking (p. 216).) As in the car accident episode, the sense of timelessness that Stephen experiences during his climb is associated with a sense of a new beginning that signals liberation from the past. ‘I won’t always be doing this’, he realizes, ‘One day I’ll be doing something else’ (p. 109). Hence, the novel portrays the experience of timelessness as a state that counters the kind of determinism associated with temporal processes evident, for instance, in thermodynamics: instead of a future unconditionally determined by the past, the experience of timelessness seems to indicate — to use the terminology of chaos theory — a point of bifurcation leading to liberation from the past.

This interpretation is to some extent supported by the imagery of the episode. Viewed from the ground level, the beech tree appears as a ‘dizzying maze of branches dividing and sub-dividing’ (p. 106). Significantly, the ensuing discussion on the nature of time between Stephen and Thelma also makes use of branch-like imagery: Thelma explains that the theory of possible worlds in quantum physics ‘has the world dividing every infinitesimal fraction of a second into an infinite number of possible versions, constantly branching and proliferating’ (p. 115). Instead of the notion that the future is always determined by the past, then, Thelma’s explanation suggests that each moment opens up a multitude of possible futures of which one is eventually realized.

In this light, it is not surprising that the novel continuously presents situations in which characters are forced to make significant choices. For instance, Stephen’s own coming into existence is a result of her mother’s choice between abortion and giving birth to her baby, as he painfully learns at The Bell; the novel suggests that already at the time when Douglas brought his watch to the store, Stephen already existed as a possibility: the hands of the watch, significantly enough, stood ‘at a quarter to three’ (p. 170). In the same way, the decision of Stephen and Julie to get back together is described in terms of choosing between mutually exclusive choices:

> They confronted two possibilities, equally weighted, balanced on a honed fulcrum. The moment they inclined towards one, the other, while never ceasing to exist, would disappear irrevocably. […].
>
> Their hesitation was brief, delicious before the forking paths. (pp. 59–60)

At this point it is necessary to make an observation about the use of the term *forking paths* in this passage. Given the fact that it points to the intimate link between the experience of time and making choices, it seems to allude to the forking paths famously portrayed in Jorge Luis Borges’s short story ‘The Garden of Forking Paths’ (1941). The protagonist of the story, a professor searching for a mythical labyrinth, discovers the garden of forking paths in a symbolic form on the pages of a book called *The Garden of Forking Paths*. Borges’s story eventually reveals that the book itself functions as a metaphor for time and the universe:

> The Garden of Forking Paths is an incomplete, but not false, image of the universe as Tsui Pen conceived it. In contrast to Newton and Schopenhauer, Tsui Pen did not believe in a uniform, absolute time. He believed in an infinite series of times, in a growing, dizzying net of divergent, convergent, and parallel times. This network of times which approached one another, forked, broke off, or were unaware of one another for centuries, embraces all possibilities of time.[57]

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[57] Jorge Luis Borges, ‘The Garden of Forking Paths’, in *Labyrinths: Selected Stories and Other Writings*, ed. by Donald A. Yates and James E. Irby (New York: New Directions Books, 1964), pp. 19–29 (p. 28).

In short, Borges's story conceives time creating an infinite number of parallel worlds, each of which represents one possibility in a labyrinthine universe. Using strikingly similar diction and images, McEwan employs the notion of parallel universes as a means of creating a universe in which different temporal levels continuously intersect each other. In this way, he questions the notion of uniform time and considers the possibility of making choices between different futures.

The tree house episode is also noteworthy because it introduces the idea of childhood as a metaphor for balanced individual consciousness. For Charles, who is torn between his desire to experience the childhood he apparently never had and the demands of his political career, childhood constitutes an escape route from time. 'For children, childhood is timeless', he comments on Stephen's first book, 'It's always the present. Everything is in the present tense. […] This book is not for children, it's for a child, and that child is you. *Lemonade* is a message from you to a previous self which will never cease to exist. (p. 28). Unfortunately, however, Charles's second childhood in adulthood is inauthentic because it makes him unable to cope with the reality of the present moment. Like Stephen's refusal to accept Kate's disappearance, Charles's eventual death — he is still wearing his school uniform when Stephen discovers his body — points to the negative consequences of resisting change. Significantly, Thelma makes a comparison between Charles's attitude and the resistance of scientific thinking towards change, noting that 'Charles's case was just an extreme form of a general problem' (p. 205), as both — whom the narrator describes as

Thelma's two children (p. 39) — are too arrogant, competitive, and egotistical for their own good.[58]

Following the Romantic ideal, the novel makes a different kind of childhood a metaphor for consciousness that is characterized by a creative kind of openness, concentration, and a willingness to allow chance encounters to lead one's way. In contrast to Charles's false, compulsive behaviour, such consciousness is capable of fully focusing on the present moment, as Stephen observes in Thelma's countryside garden:

> Kate would not be aware of the car half a mile behind, or of the wood's perimeters and all that lay, beyond them, roads, opinions, Government. He needed her good influence, her lessons in celebrating the specific; how to fill the present and be filled by it to the point where identity faded to nothing. He was always partly somewhere else, never quite paying attention, never wholly serious. Wasn't that Nietzsche's idea of true maturity, to attain the seriousness of a child at play? (p. 103)

It should be noted that this passage represents only one of the numerous instances in which McEwan creates a contrast between urban surroundings and the countryside. The link he creates between the latter and Kate's ability to remain focused suggests that the metaphorical child is an innocent who escapes the world into the present of its consciousness — this link is perhaps also implied in the narrator's description of Stephen's train journey from London to the countryside, which in addition to literally showing the protagonist buildings from different architectural periods, is a metaphorical journey 'from the past into the present' (p. 46) of human consciousness.

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[58] This is based on the comparison that McEwan makes between classical physics and masculine traits on the one hand and quantum physics and feminine traits on the other. He quite stereotypically thus associates classical physics with linear time and stasis, while linking quantum physics to cyclical time and change. In this sense, then, the character of Charles and classical physics reflect each other's negative qualities, the death of the former signalling the end of the latter (with her critical stance on the ideas of classical physics, Thelma obviously represents the new era of the 'feminine' quantum physics).

It is also the Modernist vision of Eliot that foregrounds such ideas. Suggesting yet another explicit link between the two texts, the second part of 'Burnt Norton' connects the concept of timelessness to an image of garden, as the speaker stresses the importance of stilling one's consciousness from the continuous flux of thought:

> Time past and time future
> Allow but a little consciousness.
> To be conscious is not to be in time
> But only in time can the moment in the rose-garden,
> The moment in the arbour where the rain beat,
> The moment in the draughty church at smokefall
> Be remembered; involved with past and future.
> Only through time time is conquered. (II, 42–49)[59]

In these lines Eliot links the consciousness of the present moment to an experience of eternity, consequently making the image of the rose garden a symbol of a mental state in which the temporal and the timeless intersect. Like A. S. Eddington's reconfiguration of the relationship between being and becoming in Davies, it suggests reconciliation between the physical and the psychological types of time, as the individual becomes aware of a meaningful relationship between the external and the inner realities.

Indeed, mirroring the reconciliation of the eternal and the temporal in Eliot's poem, Stephen and Julie overcome their estrangement at the end of *The Child in Time*. As in the case of the perception of time, the ending emphasizes the role of subjective consciousness as the place in which change — both individual and social — is initiated. 'In the wild expansiveness of their sorrow', the narrator describes the beginning of the change, 'they undertook to heal everyone and everything, the Government, the country, the planet, but

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[59] T. S. Eliot, 'Burnt Norton', p. 192.

they would start with themselves' (p. 217). Similarly foregrounding the role of timeless consciousness as a counterforce to the experience of the flowing river of time in the physical world, the novel ends with Julie giving birth to another child:

> Beyond the bed was the window through which they could see the moon sinking into a gap in the pines. Directly above the moon was a planet. It was Mars, Julie said. It was a reminder of a harsh world. For now, however, they were immune, it was before the beginning of time, and they lay watching planet and moon descend through a sky that was turning blue. (pp. 222–23)

The fact that Stephen and Julie thus find relief from their pain in their timeless condition of love points to the notion of subjective consciousness as a place untouched by the exterior world of social existence. Nevertheless, although the above passage suggests an opposition between the world outside and the happiness of the family, its celestial imagery indicates that there is also a sense of reconciliation: while Mars, as the narrator notes, is an obvious symbol of worldly realities, the descending moon implies the eventual banishing of darkness and a new beginning. Such reconciliation is also suggested by the fact that instead of turning away from the world, the consciousnesses of Stephen and Julie turn towards it in the end.

* * *

In the above subchapter I discussed how Davies and McEwan attempt to reconcile the relationship between physical and psychological time by regarding them as complementary rather than opposite concepts. Although Davies uses figurative language to a lesser extent than the other popularizers studied in this chapter, he does employ certain rhetorical strategies in order to support his argument that the two types of time belong to different levels of description, and are thus to be regarded as complementary. In addition to using analogies as illustrative devices, he finds in A. S. Eddington's words a means of describing the link between physical and psychological time: Eddington's use of parallelism, all-inclusive terms, and repetition help reconfigure the dichotomy and suggest that both are equally valid ways of understanding time. Inspired by Eddington's thought, Davies introduces similar all-inclusive terms, through which he aims to show undo dichotomies between scientific and human time, and free will and determinism.

McEwan in turn relies on characterization and reserved structural experimentation in order to juxtapose the temporal and the timeless. He repeatedly interrupts the main narrative by having the protagonist enter parallel worlds in which his consciousness becomes altered, as the strict boundaries between the past, the present, and the future break down. Moreover, McEwan's imagery at times suggests the possibility of escaping the tyranny of linear time by turning towards the timeless realm of consciousness and finding a pathway to the reconciliation of the inner and the outer, the subjective and the objective, there.

2.4 The New Physics: Conclusion

In this first analytical chapter I have focused on how the new physics of relativity theory and quantum physics have been represented in contemporary popular science writing and literature and how the two approach three shared topics: knowledge, identity, and time. Beginning with the observation that the popularization of the new physics is a relatively recent phenomenon, I proceeded to study how the two genres have explored its metaphysics, and discussed the relationship between the ideas of the new physics and their links to the three topics. I noted that popular science writing that establishes this kind of link often seeks to find in scientific theories answers and solutions to various sorts of human dilemmas, constructing their speculative theories on the authoritative basis of modern physics.

Because books seeking to create a link between the findings of the new physics and various distinctive schools of thought, such as Eastern philosophies, represent a substantial part of popularizations examining the philosophical implications of modern physics, I began my discussion with two well-known representatives of the trend: Fritjof Capra's *The Tao of Physics* and Gary Zukav's *The Dancing Wu-Li Masters*. I showed how the books utilize certain kind of figurative language in order to build an analogy between the subatomic world and the conceptual world of Eastern philosophies as mirrors of each other. Employing a similar method of argumentation, Danah Zohar in *The Quantum Self* attempts to establish correspondence between the ideas of the new physics and a model of human identity that emphasizes the fluid and interactive nature of the self.

Through their use of individual figures of speech such as metaphor, simile, antimetabole, synoeciosis, oxymoron, and various figures of repetition, the three writers seek to linguistically accommodate the idea that the macroscopic world constitutes an unbroken whole of interlinked parts that are in dynamic interaction with each other. In other words, their language is indicative of strong holism. One of the major consequences of this is that their use of figurative language gives rise to a philosophy of complementarity, which aims to replace the Aristotelian logic of either/or (the law of the excluded middle) with the multiperspectivist logic of both/and. As it seeks to acknowledge the notion that opposite qualities and concepts co-exist within the same object, the latter logic makes binary oppositions appear less sharp and absolute, buttressing the authors' argument that many problems facing individuals and society today derive from thinking guided by strict dichotomies.

In the same way, literature using the ideas and terminology of the new physics also reflects the desire to create an analogy between the microscopic and the macroscopic. Jeanette Winterson's *Gut Symmetries*, Ruth Brandon's *The Uncertainty Principle*, Tom Stoppard's *Hapgood*, and Michael Frayn's *Copenhagen* foreground the uncertain nature of human knowledge while comparing characters to subatomic particles in order to stress the fluidity and duality of the self. Although the portrayals of their characters suggest radically divided selves, these works present the idea that the relationship between the opposing traits of the self is based on complementarity rather than opposition. Hence, they too respond to the notion of quantum physics validating the logic of both/and rather than that of either/or, consequently espousing a distinctively holistic view of the world. Individual identity, like everything else in the interconnected web of the universe, is a composite of seemingly opposite qualities that exist side by side. In terms of human knowledge, in turn, literature tends to highlight a crucial problem in the philosophy of the new physics: although quantum physics places the observer at the centre of the universe, our interaction with the world places many fundamental restrictions on us, including our ability to ever know the universe, other human beings, or even ourselves.

However, in spite of the numerous, essential similarities between popular science writing and literature on the shared issues of knowledge and identity, there are significant differences. Whereas both suggest that the new physics validates a new kind of worldview that is in many ways emancipatory — the rigid logic of either/or is replaced by the more flexible logic of both/and, the notion of an atomistic self is substituted by a dynamic and multiple quantum self, and so forth — the latter also focuses on the anxieties that it produces. Winterson's characters are constantly troubled by the sense of shifting and malleable identity, which undermines their efforts of discovering certainty and solidity. For the other three writers, the difficulty of arriving at certain knowledge is linked to the notion that the self is composed of opposite qualities: Brandon's protagonist encounters the hidden roles played by the people in her life, the multiple identities of Stoppard's characters question the possibility of establishing universal moral values, and Frayn's Heisenberg is doomed to forever remain unknown to himself.

In the case of the third shared topic, time, I noted that both science and literature have explored the ways in which we experience it in order to establish its human relevance. Focusing on the relationship between physical and psychological types of time, Paul Davies's *About Time* and *God and the New Physics* feature reconciliatory attempts aiming to show that the two represent complementary rather than opposing ways of understanding time. In this sense, Davies espouses a holistic approach similar to that of Capra, Zukav, and Zohar, although he does not seek to link science to philosophy in the same way that the three do. Perhaps this is why Davies is quite cautious in his use of rhetorical figures: since he does not present a forceful argument about what time really is, being content with merely explaining his readers how the elusive concept has been understood, his writing is less figurative than that of writers who deliberately aim to unite science and philosophy. Yet, as already noted, the general framework of holistic thought is evident in his language.

Ian McEwan's *The Child in Time* features a similar reconciliatory attempt in that it emphasizes the role of subjective consciousness in establishing a meaningful relationship with the world. However, although it too explores the relationship between physical and psychological types of time, McEwan's novel extends Davies's discussion considerably. The most significant aspect of this is that it acknowledges the reality of the subjective experience in no uncertain terms, consequently testifying to the fact that Davies's treatment of the subject is rooted in major schools of artistic thought, such as Romanticism and the high Modernism of T. S. Eliot. In this way, the novel affirms the value of subjective experience in a world dominated by the authoritative theories of science and suggests that the two complement rather than clash with each other.

3. Chaos, Complexity, and Meaning

Having discussed examples illustrating the use of figurative language and the representation of science as regards the new physics, I now turn to another field of the natural sciences that many consider truly revolutionary: chaos theory and the study of complex natural phenomena. As in the previous chapter, I examine not only rhetoric and representation but also the various intersections between popularizations of the science and literature influenced by its ideas. More specifically, the analyses below focus on an overriding theme that all the texts studied in this chapter share: the relationship between chaos and order, as it is from this fundamental opposition that common concerns such as the relationship between humankind and nature, the problem of free will, and the question about the nature of human perception emerge. After briefly introducing chaos and complexity, I proceed to consider how contemporary popular science writing and literature delineate their human relevance. The popular books discussed in 3.2 are Ilya Prigogine and Isabelle Stengers's *Order out of Chaos: Man's New Dialogue with Nature* (1979), Prigogine's *The End of Certainty: Time, Chaos, and the New Laws of Nature* (1996), Paul Davies's *The Cosmic Blueprint: Order and Complexity at the Edge of Chaos* (1987), and Stuart Kauffman's *At Home in the Universe: The Search for Laws of Self-Organization and Complexity* (1995). I then analyse chaos and complexity in the fiction of Connie Willis's *Bellwether* (1996), Kate Wilhelm's *Death Qualified: A Mystery of Chaos* (1991), Michael Crichton's *Jurassic Park* (1991), William Gibson and Bruce Sterling's *The Difference Engine* (1990), Robert Littell's *The Visiting Professor*, and Martin Amis's *Time's Arrow or*

The Nature of the Offense (1991).[1] In 3.3 I examine a particular feature that in some instances has been linked to chaos theory: its allegedly Romantic nature. My examples of this trait are James Gleick's *Chaos* and Tom Stoppard's play *Arcadia*.

[1] Except for Amis's novel, analyses of this selection of chaos-inspired novels can be found in Merja Polvinen, 'Reading the Texture of Reality: Interpretations of Chaos in Literature and Literary Studies', *New Formations*, 49 (2003), 48–60. Section 3.2.2 presents more detailed readings in support of her general arguments. Moreover, Polvinen's discussion of Stoppard's play can be found in 'Chaos Theory and Literary Knowledge in Tom Stoppard's *Arcadia*', in *La conoscenza della letteratura*, ed. by Angela Locatelli (Bergamo: Bergamo University Press, 2002), pp. 135–58.

3.1 From the New Physics to Chaos and Complexity

As noted in the introduction to chapter 1, one of the revolutionary features of quantum physics is its insistence on the impossibility of attaining exact knowledge at the level of subatomic events. In mathematics the idea that knowledge could be organized into a formalized system of axioms, deduction, and proof was seriously questioned by the Austrian-born American mathematician Kurt Gödel's two incompleteness theorems in 1931. In the first theorem — which is the more famous one — Gödel argued that in all logically consistent formulations of logic and mathematics there exists true formulas that are neither provable nor disprovable. By this he suggests that the formulations of logic and mathematics are fundamentally incomplete because the consistency of formal systems cannot be proved within those systems. As Steven Best and Douglas Kellner note in their examination of twentieth-century thought, the implications of Gödel's theorem for the philosophy of science were nothing less than alarming: 'Because mathematics is the formal language of science and the standard of rational knowledge and certainty, Gödel's theorems had disturbing implications for the ideals of formalization and rigorous science' (*The Postmodern Turn*, p. 216).[2]

Although the first discoveries related to chaos theory were made already at the turn of the twentieth century, it was not until the 1960s that the world of the natural sciences was truly confronted with the implications of Gödel's observations. Scientists such as mathematicians, physicists, biologists, chemists, and ecologists began to notice that for

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[2] The short history of chaos theory given in the following two paragraphs is mainly based on Polvinen (p. 48).

some reason, simple natural phenomena tended to act in unpredictable ways. The need to create more accurate predictions led to the birth of chaos theory, which made it possible to describe the extremely complex behaviour of non-linear dynamic systems that have reached the state of chaos.

As readers of popularized accounts of chaos theory know, chaos can be detected in widely varied natural and man-made phenomena, such as waterfalls, traffic jams, the movement of animal populations, vortices created by aircraft wings, respiratory disorders, and chemical reaction rates, to name a few. A shared feature in the behaviour of such systems is their high sensitivity to very small changes, which gives rise to dramatically great consequences in a short period of time. These kinds of systems show one of the main characteristics of chaos: while processes that appear random or chaotic may be seen to follow mathematically describable laws — thus displaying an underlying order — processes that supposedly should exhibit predictable behaviour can be shown to be fundamentally chaotic. This implies that for the layman, the connotations of the word *chaos* in the study of complex phenomena are likely to be misleading, as instead of using it to refer to total randomness, scientists employ it when they talk about the non-linear yet ordered nature of chaotic systems. Instead of connoting formlessness, then, the scientific use of the term points to the idea that the final form of the system may prove impossible to predict, as the mathematician and meteorologist Edward Lorenz's famous example of the so-called butterfly effect suggests: theoretically speaking, a butterfly flapping its wings in Tokyo can create a storm in New York by affecting weather patterns through a complex chain of events. Hence, the possibility of prediction in the case of chaotic and complex systems is always limited.

Because of the radical implications of chaos theory for our knowledge of nature, many have granted it the status of a revolutionary scientific theory that deserves to be placed after relativity theory and quantum mechanics as the third revolution in twentieth-century science. 'Relativity eliminated the Newtonian illusion of absolute time and space', as the physicist Joseph Ford puts it, 'quantum theory eliminated the Newtonian dream of a controllable measurement process; and chaos eliminates the Laplacian fantasy of deterministic predictability.'[3] However, for cultural critics such as Steven Best and Douglas Kellner, such statements are debatable: in many ways chaos theory can be seen as a continuation of quantum theory, as it takes the principles of quantum mechanics from the study of the microscopic world and applies them to the study of chaotic phenomena in the macroscopic one (*The Postmodern Turn*, p. 218). Regardless of how one may want to interpret the status of chaos theory in the history of science, it seems that it in some critical ways represents a continuation of quantum physics. For instance, Best and Kellner note that both quantum mechanics and chaos theory offer 'a dynamic view of reality' (*The Postmodern Turn*, p. 219), in which complexity and unpredictability appear as crucial features. They argue that discoveries made in these fields point to a new vision of reality that is based on the idea of 'a heterogeneous system of forces that interact in complex, random, and irregular ways' (*The Postmodern Turn*, p. 219). For them, such a vision is distinctively postmodern because it aims at reconciliation between the crucial elements of Newtonian and post-Newtonian paradigms of thought (*The Postmodern Turn*, p. 219). On this view, scientists with a postmodern attitude aspire to develop

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[3] Quoted in James Gleick, *Chaos: Making a New Science* (New York: Penguin, 1987; London: Random House, 1997). Further references to this book are given in parenthesis.

> a synthetic theory where reversibility and irreversibility, chance and necessity, dynamics and thermodynamics, entropy and evolution, natural selection and self-organization […] are synthesized but in which the old paradigm applies only to certain closed subsystems of nature and in which chance, irregularities, and the dynamic movement of open systems are the rule rather than the exception. (Best and Kellner, *The Postmodern Turn*, p. 219)

Consequently, Best and Kellner argue, postmodern thinking in science seeks to go beyond various binary oppositions that it finds restrictive (*The Postmodern Turn*, p. 220). An apt example of this tendency is the relationship between order and disorder: previously seen in more or less antithetical terms, order and disorder are seen in chaos theory as mutually inclusive, intertwined concepts — 'as a kind of order emerges out of chaos, so chaos underlies order' (*The Postmodern Turn*, p. 220), as Best and Kellner put it using an exemplary antimetabole. As we shall see below, both popular science writing and literature are also concerned with such reconfiguration of established oppositions.

3.2 The Chaos of Our World: Order and Disorder in Nature and Human Life

As in the case of the popularization of the new physics, the widespread dissemination of the insights of chaos theory and complexity began in the 1980s (as I noted at the beginning of chapter 1, there was a considerable time lag between the actual discoveries of relativity theory and quantum physics, and their subsequent popularization). Like the ones on the new physics, popular books on chaos and complexity have linked the science to a multitude of topics in ways that can be rather surprising, as with explicit links established between chaos and business management, chaos and popular psychology, or chaos and esoteric thought.[4] Again, whatever one may think about the validity of such connections, they testify to the dynamic conceptual movement between different cultural areas, as terms and theories travel far from their places of origin.

3.2.1 Chaos Begetting Order: The Arrow of Time, Nature's Complexity, and Self-Organization

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[4] See, for instance, *Thriving on Chaos: Handbook for a Management Revolution* (New York: Knopf, 1987) by Tom Peters, *The Tao of Chaos: Essence and the Enneagram* (Norfolk, Conn.: Bramble Books, 1994) by Stephen Wolinsky, and *Condensed Chaos: An Introduction to Chaos Magic* (Tempe: New Falcon Publications, 1995) by Phil Hine.

The first book discussed in this subchapter, the Russian-born chemist Ilya Prigogine and the Belgian philosopher Isabelle Stengers's *Order out of Chaos*, is along with James Gleick's *Chaos* one of the seminal popularizations of chaos theory. Prigogine is today known for his work on the so-called dissipative structures, systems existing far from thermodynamic equilibrium that are able to give birth to higher levels of order — this, obviously, is the feature to which the title of Prigogine and Stengers's book refers. In the 1970s and 1980s Prigogine's research on such systems led him to argue that self-organization, a process whereby the internal organization of a system increases without being affected from the outside, can occur only in systems that are on the edge of chaotic behaviour. On the basis of his findings in chemistry, Prigogine went on to create a philosophical framework for his science, focusing especially on the role of time in the natural sciences. Indeed, in *Order out of Chaos* Prigogine and Stengers see time as the main linking factor between the natural and the social sciences on the one hand and philosophy on the other.

Although dealing with the same topic as Gleick's book, *Order out of Chaos* differs from it in two major respects. Firstly, as mentioned above, the authors' approach to chaos is based on the idea that chaotic systems give rise to spontaneous self-organization in the form of dissipative structures, hence exemplifying what N. Katherine Hayles calls 'the order-out-of-chaos paradigm' (*Chaos Bound*, p. 10). The second major difference is found in the fact that Prigogine and Stengers explicitly seek to situate their discussion of chaos in the framework of certain strands of continental philosophy.[5] Because they are interested in how

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[5] In terms of the overall tone of argumentation this means that there is a clear contrast between *Order out of Chaos* and *Chaos*: while the former occasionally aims to convey a sense of philosophical sublime, the latter is

chaos theory relates to the perception of time, they link the science to the ideas presented not only in the work of prominent scientists such as Darwin, Ludwig Boltzmann, A. S. Eddington, and Henri Poincaré but also in the thinking of philosophers such as Henri Bergson, Teilhard de Chardin, Heidegger, C. S. Peirce, and A. N. Whitehead. The authors argue that because humankind is undergoing ‘a period of transition’,[6]

> there is a need for new relations between man and nature and between man and man. We can no longer accept the old a priori distinction between scientific and ethical values. This was possible at a time when the external world and our internal world appeared to be in conflict, to be nearly orthogonal. Today we know that time is a construction and therefore carries an ethical responsibility. (p. 312)

Although both Gleick and Prigogine and Stengers represent chaos theory as a revolutionary science, it is evident that the link the latter establish between the science and an explicit call for a new kind of morality separates it from Gleick’s treatment of the same subject, which avoids linking science to philosophy.[7]

The scientific basis of Prigogine and Stengers’s philosophical vision is the observation that there are two kinds of temporal processes in the universe: reversible (the movements of planets, for instance) and irreversible (thermodynamic processes). Their main argument is

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much more down to earth with its references to popular culture and a narrative pattern that suggest a suspense story (Cordle, p. 78).

[6] Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man’s New Dialogue with Nature*. (New York: Bantam Books, 1984; London: Fontana, 1985), p. xxx. Further references to this book are given in parenthesis.

[7] This is characteristic of many popular science books that represent what Martin Eger calls the new epic of science, which for him is basically ‘the story of evolution: evolution explicated in greater detail than ever before, deepened, unified, extended far beyond biology — “universal” or “cosmic” evolution’ (p. 191). As in the case of much popular science studied in my thesis, the new epic of science aims through the theme of evolution to reconcile science with the concerns of human life, thus showing that even though the wonderfully complex modern science ‘cannot affect our self-concept *directly*’, its metaphors do affect society through their ‘action-orienting power’ (Eger, p. 203; emphasis original).

that non-equilibrium is the fundamental source of order at both macroscopic and microscopic levels, as '*nonequilibrium brings "order out of chaos"*' (p. 287; emphasis original). Since irreversible processes can proceed only from the past towards the future, the authors view the new science of chaos as a rediscovery of irreversible time. Indeed, for Prigogine and Stengers irreversible processes constitute the rule rather than the exception in nature because they occur frequently not only at the macroscopic level but also at the microscopic one. The authors even speculate that 'it would be quite appealing if atoms interacting with photons (or unstable elementary particles) already carried the arrow of time that expresses the global evolution of nature' (p. 288). In short, then, with its claim that irreversibility is an inherent property of matter, *Order out of Chaos* is basically a reinterpretation of the second law of thermodynamics in which the arrow of time has a distinctively creative role.

For Prigogine and Stengers, the rediscovery of time in chaos theory has many significant implications for certain deeply entrenched dichotomies in Western culture and thinking. Perhaps the most important of them is the dichotomy between the concept of being (timelessness) and that of becoming (temporality), which they see reflecting the relationship between classical (Newtonian) science and the new science of chaos. The authors' ambitious aim is to show that the newly found temporality can provide a solution for the long-standing philosophical problem about the fundamental nature of existence. At the heart of Prigogine and Stengers's argument is the idea that whereas the world of physics has for a long time been dominated by the notion of reversible time, other sciences such as evolutionary biology as well as the general human experience of life are based on the recognition that time flows irreversibly from the past to the future. In other words, the authors see the opposition between being and becoming being reflected not only in the opposition between the two cultures of the natural sciences and the rest of the culture but also in the one between physics and biology, arguing that the rediscovery of time — or, more specifically, the rediscovery of the laws of thermodynamics — can help us build a bridge between them.

Noting at the beginning of *Order out of Chaos* that ‘there is an obvious contradiction between the static view of dynamics and the evolutionary paradigm of thermodynamics’ (p. xxix), the authors go on to propose that the recognition of entropy as a creative process has important consequences for our understanding of matter. ‘This transition’, they write, ‘leads to a new concept of matter, matter that is “active,” as matter leads to irreversible processes and as irreversible processes organize matter’ (p. xxix). In this passage we can see how they use the syntactic form characteristic of antimetabole in order to foreground the intimate link between one-way temporality and matter in the new science of chaos: the reversal of the main terms helps emphasize the idea that matter is active rather than passive, as self-organization is necessarily a one-way process leading from chaos to the emergence of high-level order. Moreover, in terms of the authors’ aim to reconcile the opposition between being and becoming, it supports the claim that ‘time and reality are closely related’ (p. xxix), the antimetabole linking the human experience of the one-way flow of time to the view of reversible time prevalent in physics — this bears close resemblance to the reconciliatory attempts of Paul Davies and Ian McEwan discussed in 2.3. In this way, then, the notion of classical and quantum physics that the human experience of time is an illusory phenomenon is questioned by linking it to idea that matter is constantly moulded by irreversible, thermodynamic processes.

Prigogine and Stengers also seek to reconcile the relationship between being and becoming through other means. As noted in many analyses in my thesis, arguments aiming to undo an opposition between two concepts often employ the rhetorical strategy of subjecting the opposing terms to a third, all-inclusive term. In *Order out of Chaos* we can see how the authors undo the dichotomy between being and becoming by subjecting it to the microscopic theory of irreversibility. ‘Let us notice’, Prigogine and Stengers remind their readers, ‘that initial conditions, as summarized in a state of the system, are associated with Being; in contrast, the laws involving temporal changes are associated with Becoming’ (p. 310). Then, instead of confirming that there is an antithetical relationship between being and becoming, the authors suggest that the two are expressions of ‘a more subtle form of reality that involves both laws and games, time and eternity’ (p. 310). On this view, then, being and becoming are interrelated expressions of the same underlying reality and not mutually exclusive concepts as such.

In addition to reconfiguring the relationship between these crucial concepts, Prigogine and Stengers aim to show the importance of irreversibility from the viewpoint of humankind. In the first chapter of *Order out of Chaos* they state that one of most serious problems modern humankind has to confront is alienation from natural surroundings. ‘How can we recognize ourselves in the random world of the atoms?’, they ask, ‘Must science be defined in terms of rupture between man and nature?’ (p. 3). Prigogine and Stengers proceed to persuade their readers of the new science’s ability to build a bridge between humankind and nature in the same way as they did in the case of the dichotomy between being and becoming: subjecting the concepts to irreversibility. The authors argue that both humankind and nature emerge from the common ground of irreversible processes operating on matter, as human beings perceive time as a one-way phenomenon that proceeds from the past to the future, and nature experiences temporality in the form of evolutionary change. In this way, the bridge built by the incorporation of an all-inclusive third term makes humankind and nature parts of what the authors call ‘an evolutionary paradigm’ (p. 298) — a view closely related to Best and Kellner’s notion of chaos and complexity as fundamentally dynamic phenomena.

In the case of the dichotomy between the natural sciences and the rest of the culture, Prigogine and Stengers again suggest that the terms are opposed to each other only in our minds. They first note how modern physics ‘recognizes that, for an interaction to be real, the “nature” of the related things must derive from these relations, while at the same time the relations must derive from the “nature” of the things’ (p. 95). This antimetabole emphasizes the essentially participatory nature of being in the world: as observers in the world, we must make our observations within rather than outside the system — or, as the authors cite Maurice Merleau-Ponty, ‘since we are inside truth and cannot get outside of it, all that I can do is define a truth within the situation’ (quoted in Prigogine and Stengers, p. 299). Consequently, Prigogine and Stengers argue, there cannot exist any fundamental gulf between physics and the rest of the culture: ‘As scientists [physicists] belong to their culture, to which, in their turn, they make an essential contribution’ (p. 299). Hence, to formulate the same idea using an antimetabole, physics influences the rest of the culture in the same way the rest of the culture influences physics. This reconfiguration thus suggests a relationship that is essentially dialogic: just as humankind and nature are the twin children of irreversibility, physics is a product of an underlying culture, with close links to other cultural areas.[8]

Prigogine's last book, *The End of Certainty*, which was published in English six years before his death, uses more or less the same arguments as *Order out of Chaos*. In contrast to the early best-seller, however, it focuses specifically on the question of time in the context of Prigogine's proposal for a 'unified formulation of quantum theory' that functions as the scientific basis for the book's aim to create 'an "intermediate" description that lies somewhere between the two alienating images of a deterministic world and an arbitrary world of pure chance'.[9] With a reconciliatory aim similar to that of *Order out of Chaos*, this book too presents an explicit call for a new kind of philosophical vision. 'Our belief', Prigogine writes, 'is that our own age can be seen as one of a quest for a new type of unity in our vision of the world, and that science must play an important role in defining this new coherence' (p. 186).

The crucial issue in *The End of Certainty* concerns the link between time and the problem how the relationship between determinism and indeterminism should be defined. 'Is the future given', Prigogine asks in his introduction to the book, 'or is it under perpetual construction? A profound dilemma for all of mankind, as time is the fundamental dimension of our existence' (p. 1) — a problem similar to the one concerning the relationship between being and becoming, to which he returns in his discussion. He then proceeds to outline the attitude of his position, which he calls 'the *physics of*

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[8] Note how closely this resembles the theoretical model of the relationship between science and literature presented in the introduction.

[9] Ilya Prigogine, *The End of Certainty: Time, Chaos, and the New Laws of Nature* (New York: Free Press, 1997), p. 189. Further references to this book are given in parenthesis.

nonequilibrium processes' (p. 3; emphasis original), towards time by introducing two metaphors: 'We are actually the children of the arrow of the time, of evolution, not its progenitors' (p. 3). By combining metaphor and antithesis in a single sentence, Prigogine grants time an essentially creative role in the universe. Instead of seeing the flow of time as a subjective — and consequently, an illusionary — phenomenon as many physicists do, he argues that it is present in the same fundamental physical processes that first gave rise to life, thus repeating his argument in *Order out of Chaos*.

In his discussion Prigogine again approaches the question about the flow of time in the context of the relationship between being and becoming. He notes that the problem of their reconciliation has been with us since antiquity and that it was the introduction of the Newtonian worldview with its reversible time that gave being the supreme position. For Prigogine, the most important consequence of the notion of a time-reversible, or non-temporal, universe was that it made the world into a completely predictable automaton, in which 'novelty, choice, and spontaneous action are real only from our human point of view' (p. 12). In other words, the Newtonian universe banished indeterminism as an illusion. He argues that this view, which characterized Einstein's thoughts about time, is untenable because it does not take into consideration the human experience of the flow of time, which ultimately originates from the fundamental — time-asymmetrical — laws of physics (p. 13–16). Hence, he concludes, indeterminism — in the form of novelty and chance — is a fundamental property of matter, not only a fancy of the human mind (p. 16).

However, it is obvious that determinism, in the form of reversible processes, is needed in our description of the universe. Instead of abandoning it altogether, then, Prigogine wants to reconcile the 'two conflicting views of nature from the nineteenth century: the time-reversible view based on the laws of dynamics and the evolutionary view based on entropy' (p. 19). Just as with the similar reconfigurations of apparent dichotomies in *Order out of Chaos*, he does this by subjecting the two terms to an all-inclusive third term. Given the emphasis Prigogine places on irreversible temporal processes, the arrow of time is an obvious choice for such a concept:

> Once we have an arrow of time, we understand immediately the two main characteristics of nature: its unity and its diversity: unity, because the arrow of time is common to all parts of the universe (your future is my future; the future of the sun is the future of any other star); diversity, as in the room where I write, because there is air, a mixture of gases that has more or less reached thermal equilibrium and is in a state of molecular disorder, and there are the beautiful flowers arranged by my wife, which are objects far from equilibrium, highly organized thanks to temporal, irreversible, nonequilibrium processes. (p. 56)

The passage makes thermodynamic processes the origin of order, thus undoing the dichotomy between being (determinism) and becoming (indeterminism). Although for Prigogine the latter is the more fundamental of the two — it is the rule while the former is the exception — both are required in a tenable description of the universe. 'We need', Prigogine consequently proclaims, 'a "divine" point of view to retain the idea of determinism. But no human measurements, no theoretical predictions, can give us the initial conditions with infinite precision' (p. 38). Hence, while it is not possible for human observers to observe the system from the outside in order to gain absolutely precise information about it, we need to recognize the fact that the system will nevertheless develop according to deterministic laws.

Prigogine expresses the same idea in the eighth chapter of his book but this time by using a different rhetorical strategy. 'Irreversibility,' he writes, 'and therefore the flow of time, starts at the dynamical level. It is amplified at the macroscopic level, then at the level of life, and finally at the level of human activity' (p. 162). The passage uses a figure of speech called incrementum, or auxesis, which arranges a list of items in a sequence, thus epitomizing the idea that the dynamic arrow of time passes through all levels of physical existence.[10] As such, the ascending series has a distinctively reconciliatory function: it places the arrow of time at the heart of both physics and biology and gives them a common foundation in irreversible, chaotic processes.

For Prigogine, then, at the root of physical processes are laws of nature that describe possibilities rather than certainties. Quoting Vladimir Nabokov's *Look at the Harlequins!* (1974), he notes the consequences for the attempt of science to control nature: 'What can be controlled is never completely real; what is real can never be completely controlled' (quoted in Prigogine, p. 154). Placed in the context of Prigogine's argument, Nabokov's antimetabole foregrounds the idea that while we can try to understand reality, we can never control it because of its essentially stochastic nature, whose complexity our measuring devices are unable to measure with complete accuracy. In this sense, Prigogine argues, the reversible-time universe of classical physics is a universe lacking the characteristic, dynamic features of human reality: communication, memory, and history, which as phenomena requiring interaction between 'the knower and the known' (p. 153) are necessarily time-irreversible processes. In order to illustrate the distance between the reversible-time universe and the world of human experience, he cites himself and Isabelle Stengers in *Entre le Temps et l'Eternité* (1988) as follows:

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[10] As Jeanne Fahnestock observes, although incrementum in classical rhetoric usually arranges words or clauses according to value or force ('Neither silver, gold, nor precious stones might be compared to her vertues'), in science it is used for creating various kinds of series on which to build arguments (p. 97).

> No speculation, no teaching has ever affirmed an equivalence between what is done and what is undone: between a plant that sprouts, flowers and dies, and a plant that resuscitates, grows younger and returns to its original seed; between a man who grows older and learns, and one who becomes a child, then an embryo, then a cell. (quoted in Prigogine, p. 154)

Note how the passage juxtaposes ascending and descending incremental series as a means of emphasizing the idea that as the timeless realm of being does not distinguish between the past and the future, there cannot be a dialogue between either individuals or the individual and the world. ‘It is this *common* arrow of time’, Prigogine thus maintains, ‘that is the necessary condition of our communication with the physical world; it is the basis of our communication with our fellow human beings’ (p. 54; emphasis original).

Having thus established an intimate link between the world of irreversible processes and humankind, Prigogine sums up his philosophy by asserting that ‘time precedes existence’ (p. 163). In order to illustrate how humans are bound to time, he quotes Jorge Luis Borges’s ‘A New Refutation of Time’ (1962):

> And yet, and yet […] denying temporal succession, denying the self, denying the astronomical universe, are apparent desperations and secret consolations. […]. Time is the substance I am made of. Time is a river which sweeps me along, but I am the river; it is the tiger which destroys me, but I am the tiger; it is a fire which consumes me, but I am the fire. The world, unfortunately, is real; I, unfortunately, am Borges. (quoted in Prigogine, p. 187)

Here Borges uses a series of metaphors to emphasize the essentially dynamic nature of time. Interestingly, he combines his metaphors with antimetaboles by linking the first person singular pronoun and each of the metaphors to each other. In the context of Prigogine’s argument, the repetition of syntactic reversals foregrounds the idea that identity and time cannot be separated from each other, for it is the former that both is born and dies through the latter.

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Whereas *Order out of Chaos* places heavy emphasis on the role of time in thermodynamic processes, Paul Davies's *The Cosmic Blueprint* approaches chaos and complexity by focusing on the relationship between accident and design in the creation of natural complexity, at the same time granting nature an essentially innovative role as an unpredictable creator of complexly organized phenomena, as Prigogine and Stengers do. For Davies, the question about the creativity of the universe boils down to two interrelated, fundamental questions: 'Are the seemingly endless varieties of natural forms and structures, which appear as the universe unfolds, simply the accidental products of random forces? Or are they somehow the inevitable outcome of the creative activity of nature?'[11] Although Davies's formulation suggests that we might think of accident and creativity as opposing concepts, the book nevertheless argues that self-organization in complex phenomena requires the interaction of the two. Hence, as in Prigogine and Stengers's philosophy of irreversibility, there is in *The Cosmic Blueprint* an underlying attempt to reconcile the relationship between chance and determinism in order to offer readers a new, balanced vision of nature.

Davies links his discussion of this relationship to the exploration of the relationship between reductionistic and holistic views of nature. Noting that 'there was [...] already present in ancient Greece the deep conflict between holism and reductionism which persists to this day' (p. 7), he argues that these seemingly opposing views also need to be reconciled

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[11] Paul Davies, *The Cosmic Blueprint: Order and Complexity at the Edge of Chaos* (London: Heinemann, 1987; London: Penguin, 1995), p. 1. Further references to this book are given in parenthesis.

with each other. Davies observes that scientists working in the field of contemporary physics and chaos theory are aiming to complement the method of reducing the whole to its constituent parts with the distinctively holistic approach of examining how the interaction of those parts functions to give rise to the whole (p. 8). In this sense too Davies's effort is much related to Prigogine and Stengers's attempt of constructing an argument in favour of a view in which apparently antithetical concepts are treated on the basis of complementarity rather than opposition.

Davies begins his discussion on chaos by taking a look at the differences between the Newtonian universe and the world of chaos and complexity. In order to illustrate how the former is characterized by all-embracing determinism, he quotes the French mathematician and theoretical physicist Pierre Laplace's famous description of a hypothetical entity that knows everything about the physical world with infinite precision:

> Consider an intelligence which, at any instant, could have a knowledge of all forces controlling nature together with the momentary conditions of all the entities of which nature consists. If this intelligence were powerful enough to submit all this data to analysis it would be able to embrace in a single formula the movements of the largest bodies in the universe and those of the lightest atoms; for it nothing would be uncertain; the future and the past would be equally present to its eyes. (quoted in Davies, p. 10)

By imagining such an entity — which is often referred to as *Laplace's demon* — Laplace draws attention to the fact that in the Newtonian universe, the movement of every particle has been determined from the very first moment they came into existence (see Davies, p. 10). From the viewpoint of humankind, Davies notes, this amounts to denial of any kind of free will, as those particles are also the building blocks of human beings (p. 11). Neither the universe nor its inhabitants, then, seem to be able to make free-willed choices because 'every event happens *of necessity*' (Davies, p. 11; emphasis original).

Chaos theory, in contrast, appears to counter the implications of Newton's universe in some fundamental respects. When we observe systems that behave chaotically, it is often impossible to precisely calculate the initial conditions that determine their development, and our observational errors tend to increase exponentially, as the systems develop over time (Davies, pp. 53–54). For this reason, the direction of the development of chaotic systems is very difficult predict, and scientists are forced to just describe them instead of making predictions about their behaviour (Davies, p. 54).

Davies points out, however, that the differences between linear (Newtonian) and non-linear (chaotic) systems do not have to imply that there is a genuine opposition between the determinism of the former and the randomness of the latter. Chaos, he argues, is 'a bridge between chance and necessity — between the probabilistic world of coin tossing and roulette and the clockwork universe of Newton and Laplace' (p. 52). Hence, he employs the rhetorical strategy of subjecting the two seemingly opposite concepts to an all-inclusive third term. On the other hand, it should be noted that like Prigogine in *The End of Certainty*, Davies is not really granting the terms equally weighted roles, as chance is in the end given a more fundamental role than necessity. Although we may theoretically conceive that the universe features both aspects, he continues, in practice determinism must be considered 'a myth' (p. 55). In this sense, then, the subjecting of chance and determinism to chaos in *The Cosmic Blueprint* is used to the same end as the subjecting of being to becoming in Prigogine and Stengers's *Order out of Chaos*. Indeed, the end of Davies's fourth chapter makes this point for the practical side of science through antithesis: 'But in reality our universe is not a linear Newtonian mechanical system; it is a chaotic system' (p.

56), thus reformulating the relationship between linearity and non-linearity by more or less reversing the earlier hierarchy between them.

Examining the philosophical implications of a non-linear physical world, Davies links the question about the relationship between chance and necessity to the dilemma of predestination, and it is here that his central metaphor, the cosmic blueprint, assumes its rhetorical force. Davies notes that previous paradigms of thought have given rise to essentially ‘gloomy’ (p. 200) worldviews: the fate of the universe both in the Newtonian and the thermodynamic paradigms is ‘inevitable’ (p. 199) — slavish stasis and degeneration, respectively — and creation in them is a one-time affair that disallows further novelty. Following Bergson as well as Prigogine and Stengers, he then goes on to define the relationship of the old and the new paradigms through antithesis. In the new paradigm, he argues

> Creation is not instantaneous; it is an ongoing process. The universe has a life history. Instead of sliding into featurelessness, it rises out of featurelessness, growing rather than dying, developing new structures, processes and potentialities all the time, unfolding like a flower. (p. 200)

The simile between the creative unfolding of the universe and the unfolding of a flower functions much like the cosmic blueprint metaphor. Both suggest that the universe is predestined in the sense that since its birth, it has been capable of creating conditions that are conducive for self-organization and consequently, for the appearance of life. They also have a distinctively reconciliatory function, which is evident in Davies’s description of the so-called predestinist theory (to which he subscribes):

> Predestiny — or predisposition — must not be confused with predeterminism. It is entirely possible that the properties of matter are such that is does indeed have a propensity to self-

> organize as far as life, given the right conditions. This is not to say, however, that any particular life form is inevitable. In other words, predeterminism (of the old Newtonian sort) held that everything *in detail* was laid down from time immemorial. Predestiny merely says that nature has a predisposition to progress along the general lines it has. It therefore leaves open the essential unknowability [*sic*] of the future, the possibility for real creativity and endless novelty. In particular it leaves room for human free will. (p. 201; emphasis original)

On the basis of this passage, Davies seems to be arguing for the existence of a blueprint that, in contrast to the Newtonian model of a clockwork universe, constitutes a general rather than detailed outline. Although the evolution of the universe is predestined in the sense that the universe creates itself according to the laws of complexity, the results of this creativity cannot be determined in advance. Interestingly, it is in this feature that Davies finds the importance of complexity for human life, writing that 'the knowledge that our presence in the universe represents a *fundamental* rather than an *incidental* feature of existence offers, I believe, a deep and satisfying basis for human dignity' (p. 203; emphases original). Thus, he regards humankind as an expression of the creativity of the universe that has its basis in self-organizing processes — processes that embody both chance and necessity.

For Davies, one of the most important consequences of such observations is the realization that complexity is actually a predominant rather than marginal feature of nature (p. 22). He begins his discussion of complexity by quoting Bergson in *Creative Evolution* (1907) as follows: 'The universe is not made, but is being made continually' (quoted in Davies, p. 255). Placed in the context of Davies's argument about the status of complexity in nature, the simple syntactic form of Bergson's antithesis makes a rhetorically powerful and straightforward statement: in no uncertain terms it asserts that complexity and chaotic phenomena play more fundamental and dynamic roles in nature than their more organized counterparts. Like Prigogine and Stengers, however, Davies is by no means seeking to dismiss the role of linear systems; he uses the antithesis to reconfigure the opposition while later revealing its seeming nature.

The tenth chapter of *The Cosmic Blueprint* links the discussion on creativity to the question about the relationship between reductionism and holism. Davies notes that while the various Theories of Everything in subatomic physics are focused on discovering the smallest particles of matter in a purely reductionistic fashion, the interdisciplinary study of physics and biology is interested in relationships inside wholes, thus attempting to formulate what he calls the Theory of Organization (p. 138). He finds an apt example for his position in the thinking of the biologist Peter Medawar, who draws a comparison between 'the emerging conceptual levels in physics and biology and the levels of structure and elaboration in mathematics' (p. 146). 'He sees', Davies writes,

> this relationship between mathematical levels in a hierarchy of enrichment as paralleled in biology. Starting with atoms, building up through molecules, cells and organisms to conscious individuals and society, each level contains and enriches the one below, but can never be reduced to it. (p. 146)

Because Medawar juxtaposes two series in his argument — the validity of which Davies obviously accepts — he actually creates what is in rhetorical terms called a double hierarchy argument. Functioning much like metaphors, such arguments tend to transfer the qualities or implications of one hierarchy on another for comparison (Fahnestock, pp. 105–08). Although readers are not given the former (mathematical levels) series in this passage, it is clear from the latter that both of them feature an ascending incrementum, which epitomizes the idea of increasing complexity whose properties can never be reduced downwards. Hence, placed in the context of Davies's argument, the series suggests an essentially holistic philosophy, in which the various systems are fractal-like entities with their nested constituents.

Although the series thus figuratively illustrates the idea behind the argument 'that each new level of organization and complexity in nature demands its own laws and principles' (Davies, p. 191), it does not perhaps in itself foreground the fact that the relationships of neighbouring levels are always based on interaction. For this purpose, Davies introduces the neurologist Roger Sperry's theory of mental events. Taking the holistic position, Sperry argues that while mental events can never be reduced to the neural events that give rise to them, they can act back on the physical components of which the human nervous system consists: neurones (see Davies, p. 191). For Davies, this means that causation can also be directed towards the lower levels, as illustrated in a citation from the neurobiologist Donald MacKay:

> In an information system, we can recognize 'informational' causality as something qualitatively distinct from physical causality, coexisting with the latter and just as efficacious. Roughly speaking, whereas in classical physics the determination of force by force requires a flow of energy, from the standpoint of information theory the determination of form by form requires a flow of information. The two are so different that a flow of information from A to B may require a flow of energy from B to A; yet they are totally interdependent and complementary, the one process being embodied in the other. (quoted in Davies, p. 192)

In this passage the interdependent nature of lower and upper levels is suggested through an antimetabole-like reversal in the last sentence. This simple reversal epitomizes the idea that there is no reason why causative interaction should not take place between different levels in addition to happening simultaneously at different individual levels.

In this way, then, Davies argues that reductionism and holism should not be seen as opposite but complementary concepts. He also captures this idea through a simple analogy between scientific thinking and the set-up of the computer. While scientific approaches to nature can roughly be divided into reductionistic and holistic ones, in the world of computing there is a similar division between hardware and software: whereas the ‘laws’ of the former describe the electrical activity of the computer’s circuits and switches, those of the latter describe the same activity as, for instance, a solution to a mathematical problem by using equations that are meaningless at the level of hardware laws (Davies, p. 144). Davies’s point is that the two descriptions are complementary rather than opposite, as there are different kinds of descriptions for different levels, with each description being valid at its own level. Consequently, Davies argues, it might be possible for us to see the reconciliation of reductionism and holism taking place in nature. In his reconciliatory ‘third alternative’ (p. 142) for the reductionism versus holism question, the hardware laws of physics would give rise to emergent software laws that ‘govern the behaviour of organization, information and complexity’ (p. 144). For Davies, this view would validate both reductionism and holism by a model of how simple laws generate incrementally increasing complexity and variety.

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The theme of evolution that surfaces in Paul Davies’s *The Cosmic Blueprint* dominates the American theoretical biologist Stuart Kauffman’s *At Home in the Universe*. The major difference between these two books is that whereas Davies discusses chaos mainly in the context of physics and cosmology, Kauffman approaches it through the framework of a field called bioinformatics, a mixture of computational mathematics and molecular biology.

In *At Home in the Universe*, which is a popularized version of Kauffman's first book, *The Origins of Order: Self-Organization and Selection in Evolution* (1993), he studies the sources of order in the universe, arguing that life may have begun from a simple and predictable self-organizing event. From the viewpoint of evolutionary theory, Kauffman's provocative argument challenges some of the main assumptions in Darwin's account of evolution: instead of placing emphasis solely on natural selection in the production of order, he argues that it is the combination of natural selection and the ability of complex systems to spontaneously organize themselves into increasingly higher levels of order that ultimately produces the order we see not only in biological but also in cultural evolution.[12] In his first chapter Kauffman defines the relationship between the two views of evolution as follows:

> Without a framework to embrace both self-organization and selection, self-organization has been rendered almost invisible, like the background in a gestalt picture. With a sudden visual shift, the background can become the foreground, and the former foreground, selection, can become the background. Neither alone suffices. Life and its evolution have always depended on the mutual embrace of spontaneous order and selection's crafting of that order. (pp. 8–9)

The antimetabole of the second sentence clearly epitomizes the idea that self-organization and natural selection are inextricably intertwined phenomena. The passage also shows that Kauffman seeks to reconfigure the relationship between self-organization and natural selection, suggesting that it is in fact the former that is the more fundamental of the two and consequently, reversing the original hierarchy. In other words, then, like Prigogine and

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[12] Stuart Kauffman, *At Home in the Universe: The Search for Laws of Self-Organization and Complexity* (New York: Oxford University Press, 1995), p. vii. Further references to this book are given in parenthesis.

Stengers, and Davies, he attempts to reconcile views that are seen opposite in their implications.

For Kauffman, the question about the relationship of the two sources of order in evolution is not only a scientific problem. He argues that the emphasis Darwinism places on the blind and purposeless nature of natural selection has for long affected our sense of meaning as human beings:

> We live in a world of stunning biological complexity. Molecules of all varieties join in a metabolic dance to make cells. Cells interact with cells to form organisms; organisms interact with organisms to form ecosystems, economies, societies. Where did this grand architecture come from? For more than a century, the only theory that science has offered to explain how this order arose is natural selection. As Darwin taught us, the order of the biological world evolves as natural selection sifts among random mutations for the rare, useful forms. In this view of the history of life, organisms are cobbled-together contraptions wrought by selection, the silent and opportunistic tinkerer. Science has left us as unaccountably improbable accidents against the cold, immense backdrop of space and time. (p. vii)

As in Prigogine and Stengers — and to a lesser extent, in Davies — there is a strong sense of a desire to articulate a new vision of the world. Kauffman states that 'we need to paint a new picture' (p. 9) that corrects the mistaken assumptions of previous science, at the same time arguing for its meaningfulness for humankind. Moreover, Kauffman's formulation of the second and third sentences indicates that his vision is distinctively holistic: using gradatio, which through repetition joins together the various levels of complexity, he foregrounds the idea that we need to focus on the interaction of the parts in order to see the whole, as the emergent properties of complex systems cannot be explained through reduction. Like Davies, then, Kauffman sees that humankind is not an accidental but a likely outcome of interaction between self-organization and natural selection.

Having thus identified the major problem in the Darwinian worldview as a sense of alienation between humankind and the world, Kauffman proceeds to outline a philosophy that might remedy the situation. He introduces this problem at the beginning of the first chapter, which discusses the various attitudes to the concept of order in the history of biology and physics, by employing one of the most prominent tools of storytelling in popular science writing: anecdote. In a lengthy autobiographical description, Kauffman recalls a visit to the famous Santa Fe Institute, an important centre of complexity studies situated in New Mexico:

> Some months ago, I found myself at lunch with Gunter Mahler, a theoretical physicist from Munich visiting the Santa Fe institute, where a group of colleagues and I are engaged in a search for laws of complexity that would explain the strange patterns that spring around us. Gunter looked northward, past piñon and juniper, taking in the long view of Colorado, and somewhat astonished me by asking what my image of paradise was. As I groped for an answer, he proposed one: not the high mountains, or the ocean's edges, or flat lands. Rather, he suggested, just such terrain as lay before us, long and rolling under strong light, far ranges defining a distant horizon toward which graceful and telling land forms march in fading procession. For reasons I do not completely understand, I felt he was right. We soon fell to speculation about the landscape of East Africa, and wondered whether, in fact, we might conceivably carry some genetic memory of our birthplace, our real Eden, our first home. (p. 3)

Read in the context of Kauffman's claim that Darwinian evolutionary theory has decisively contributed to the alienation of humankind from the world, the anecdote obviously points to the possibility of rediscovering our origins through a novel scientific worldview, particularly the one offered by the studies of complex phenomena. In other words, Kauffman's aim is the reconciliation of humankind and nature through the argument that because the former is an 'expected rather than vastly improbable' (p. viii) outcome of self-organization, it is therefore capable of enjoying meaningful existence through the rediscovery of the 'sense of our own deep worth' (p. 5). Kauffman epitomizes the consequences of this idea through a slogan-like, textbook antithesis coupled with the anaphoric repetition of the first-person plural pronoun: ‘If I am right, the motto of life is not We the improbable but We the expected’ (p. 45).

In the third chapter Kauffman notes that the notion of humankind as a probable product of a self-organizing process poses a serious challenge to the prevailing theory of evolution, which emphasizes the role of chance in the early replication of RNA molecules. He states that one of his major tasks is to persuade his readers of the validity of the ‘renegade view’ that ‘life is not shackled to the magic of [RNA] replication’ (p. 47). In order to foreground how strongly the traditional views link evolution to the mechanisms of replication and genetic coding for proteins, Kauffman formulates a sentence that reverses the concepts as follows: ‘Evolution cannot proceed without these mechanisms, and we cannot have these mechanisms without evolution to tinker them together’ (p. 72). Using the form of antimetabole, he shows how evolution and chance are inextricably linked to each other in the orthodox (Darwinian) theory of evolution. In his argument Kauffman thus seeks to question this link by suggesting that life may have begun through self-organizing chemical reactions in autocatalytic sets of molecules.

Illustrating how such sets function, Kauffman creates a series that progresses from the beginning to the end and then begins all over again. ‘What I call a collectively autocatalytic system’, he writes, ‘is one in which the molecules speed up the very reactions by which they themselves are formed: A makes B; B makes C; C makes A again’ (p. 49). Through the repetition characteristic of gradatio, Kauffman’s series offers a convenient way of emphasizing causal continuity in molecular interaction. As such, its form epitomizes the notion of living organisms as sets capable of accelerating chemical reactions by themselves, thus giving linguistic form to the idea of circular continuity observed in the ‘self-propelling loops’ (p. 49) to which autocatalytic processes give birth. Kauffman draws an analogy to life at the macroscopic level and uses repetition to achieve a similar sense of circularity in order to argue that autocatalytic processes also occur in culture. ‘What if we think of goods and services as symbol strings that we humans can use as “tools,” “raw materials,” and “products?”’, he asks, ‘Symbol strings act on symbol strings to create symbol strings’ (p. 283). In the same way, in economy ‘the goods and services previously “invented” create novel opportunities to create still more goods and services’ (p. 291). Being essentially circular in their functioning, the symbol strings of our culture are thus analogous to autocatalytic sets in chemistry. ‘Somehow,’ Kauffman goes on while discussing the emergence of a global civilization,

> the string of images we have discussed press themselves on me. The swirl of transformations of ideologies, fashions begetting fashions begetting fashions, cuisines begetting novel cuisines, legal codes and precedents begetting the further creating of law, seem similar in as yet unclear ways to model grammar worlds with their eggs, jets, and mushrooms. (p. 289)

In this passage too Kauffman uses various forms of repetition to foreground the universality of self-sustaining evolutionary processes building on themselves in an autocatalytic fashion. The second clause of the second sentence simply repeats two single words in the fashion of ploche, while the third clause uses epanalepsis. The fourth clause of the same sentence in turn uses the phrase *legal codes and precedents* as a synecdochic means of referring to *the further creating of law*, thus producing a similar sense of circularity. (Below I discuss how the notion of cultural concepts giving birth to cultural concepts through a circular loop is featured in Connie Willis’s *Bellwether*.)

Throughout *At Home in the Universe* Kauffman maintains that because such sets are necessarily complex (‘Simpler systems simply do not achieve catalytic closure’ (p. 69)), they embody holistic principles. He argues that ‘life emerged […] not simple, but complex and whole’ (pp. 47–48) in interlinked molecular chains, using antithesis to question the traditional assumption that the processes operating on matter during the early days of the universe were somehow less complex than their later counterparts. For him, such processes exemplify the holistic notion ‘of organisms as autopoetic wholes in which each part exist[s] both for and by means of the whole, while the whole exist[s] for and by means of the parts’ (p. 274). Kauffman’s use of antimetabole implies strong causal interdependence between the whole and the parts. He hence proposes that their interaction makes them inseparable from each other and that they are equally important in status. By defining the relationship between the whole and its parts through a syntactic reversal, Kauffman is able to create a rhetorically persuasive argument against ‘the image of the genome as the central directing agency that commands the molecular dance’ (p. 69) — the antimetabole suggests that a holistic approach focuses on the equality of the whole and the parts, cells and organisms creating themselves without being directed by such an agency.

By emphasizing the importance of taking a holistic approach to the question about life’s origin, Kauffman seeks to redefine the relationship between the genotype (the genetic constitution of an individual organism) and the phenotype (the observable characteristics of organisms). While the orthodox theories of evolution separate the former from the latter in cells and organisms, Kauffman asserts that ‘with autocatalytic sets, there is no separation between genotype and phenotype’ (p. 73). In this way, the notion of autocatalysis in Kauffman’s thinking serves to introduce a new, inclusive term that unites two concepts traditionally regarded as being either opposed to or distinct from each other. By undoing the antithesis between the genotype and the phenotype, Kauffman is able to challenge the status of natural selection as the only source of order in life: instead of requiring separate genomes to become alive, systems produce their own genetic material by acting as their own genomes (p. 73). This redefinition is important because it seeks to achieve reconciliation between the Darwinian view of evolution and Kauffman's own holistic, order-for-free approach, and its implications for humankind are summed up by Kauffman through antithesis: 'We are the children of twin sources of order, not a singular source' (p. 71). Note also how he in another chapter expresses the same idea through a juxtaposition of opposite concepts: 'Whence the order out my window? Self-organization *and* selection, I think. We, the expected, *and* we, the ad hoc. We, the children of the ultimate law. We, the children of the filigrees of historical accident' (p. 185; emphases original). In this passage the opposites are juxtaposed in the manner of synoeciosis, which further foregrounds their equal status in Kauffman's vision.

Like the two popular accounts of chaos and complexity discussed above, *At Home in the Universe* is concerned with presenting the dialectic of chance and necessity as the necessary condition for self-organization. This is evident especially in Kauffman's discussion on one of the crucial concepts of the book: the 'edge of chaos' (p. 28). The edge of chaos refers to the idea that productive complexity emerges in the middle of the continuum between order and chaos, rather than at its ends (pp. 26–29, 86–92, 257–64). As such, it is an area of phase transition (the transformation of a thermodynamic system from one phase to another, such as solid ice turning to liquid turning to gas), in which chaotic behaviour is most likely to take place. Located at the intersection of order and chaos, the edge of chaos is a distinctively reconciliatory concept suggesting that the relationship of order and chaos is based on complementarity rather than opposition, and in this sense we could think of it as another all-inclusive third term whose function is to unite two seemingly opposite terms. Kauffman consequently notes that ‘the fate of all complex adapting systems in the biosphere — from single cells to economies — is to evolve to a natural state between order and chaos, a grand compromise between structure and surprise’ (p. 15) — note how the alliteration in *structure and surprise* emphasizes the equality of chaos and order in relation to each other.[13]

The idea that order and chaos meet each other with productive results at the middle of a continuum is also discussed in the tenth chapter, but here Kauffman uses a graph to illustrate it (this particular example concerns ecosystems heading towards the edge of chaos). Because the graph shows the various intermediate points along the continuum from order to chaos, it can be thought of as a visual incrementum that represents a series progressing from an ordered state towards the edge of chaos. Rhetorically speaking, the argumentative function of the graph decreases the sense of separation between order and chaos because it presents the difference between them as a difference of degree on a connected scale. Hence, rather than constituting opposite poles that are not connected to

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[13] Compare this with the similar use of alliteration in Francis Galton’s discussion on the relationship between inheritance and education, or ‘nature and nurture’. Through the repetition of initial consonants in his famous phrase, Galton is able to neatly encapsulate his argument about the factors influencing the development of individuals. Jeanne Fahnestock notes that although the use of alliteration in this particular phrase may indicate that the terms are on a par with each other, it nevertheless also points to the possibility of an antithetical relationship, as Galton thought nature had the upper hand in the formation of personality (pp. 167–68).

each other, chaos and order merge with each other in Kauffman's graph. In this case, then, the focus of the series is on an intermediate point rather than on its beginning or end.[14]

The importance of the edge of chaos for Kauffman's vision in *At Home in the Universe* is also evident in the discussion on the question of predictability in chaotic systems. Kauffman notes that one of the most important characteristics of systems at the edge of chaos is their unpredictability over long periods of time. 'We cannot know', he writes, 'the true consequences of our own best actions. All we players can do is be locally wise, not globally wise' (p. 29). The antithesis in this passage epitomizes the idea that in a world in which unpredictability is a rule rather than an exception, humankind should not cultivate an attitude of hubris towards nature. The title of the subchapter in turn uses a slogan-like antithesis to convey the same idea: 'Wisdom, not Power' (p. 28). As wisdom and power do not constitute a natural pair of semantic opposites, they are employed as nonce antonyms in the specific context of Kauffman's argument on predictability. This antithetical formulation questions the possibility of equating knowledge with power and control — which Kauffman sees dominating the 'Baconian tradition' (p. 302) in Western science — by suggesting that the effects of our actions always contain an element of unpredictability that might disturb the delicate balance of chaos and order at the edge of chaos in dramatic ways. It is not surprising, then, that Kauffman finds in such unpredictability 'a new philosophy of life' (p. 243) that emphasizes the importance of respecting nature instead of trying to

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[14] In her discussion on the various uses of argumentative series in science, Fahnestock notes that incremental series can in this way be employed 'to dissolve differences between categories and so reconfigure a conceptual domain, replacing differences in kind between categories by differences in degree within a new larger category' (p. 97).

dominate it: ‘Our smallest moves may trigger small or vast changes in the world we make and remake together’ (p. 243).

In spite of — or, perhaps, because of — its unpredictable nature, Kauffman sees chaos as a fundamentally creative force. This can be seen, for instance, in his discussion of co-evolution. Co-evolution refers to the idea that competing populations strive to climb up interconnected fitness landscapes to establish niches at fitness peaks. From this follows that populations transform each other’s fitness landscapes, as they adapt to their surroundings. In this process Kauffman sees three kinds of evolutionary activity: chaotic, ordered, and transitional. During the ordered phase the populations that have succeeded in establishing a niche at a fitness peak are not affected by the co-evolutionary process, whereas during the climb uphill, or the chaotic phase, fitness peaks may become difficult to reach because of swift transformations in the landscapes. Thus, the most productive type of co-evolution, Kauffman argues, occurs when populations move away from the ordered landscapes towards the more chaotic ones, consequently entering the transitional phase (p. 27; pp. 221–23).

Like autocatalysis, co-evolution is in Kauffman’s argumentation a reconciliatory term: it links biological evolution to the evolution of cultural artefacts. Kauffman points out that we usually think that evolutionary processes in biology and culture are ‘entirely different’ (p. 201), as the former is thought of as a more or less random process while the latter is regarded as characterized by human intention. He questions the validity of this antithesis by subjecting it to two new notions: while both processes are subject to the laws of co-evolution, they are also restricted by similar ‘conflicting design constraints’ that result into roughly similar ‘rugged but correlated landscapes’ (p. 192). After introducing these concepts, Kauffman observes that both types of evolutionary processes display similar patterns: as in evolutionary diversification, 'fundamental [cultural] innovations are followed by rapid, dramatic improvements in a variety of different directions, followed by successive improvements that are less and less dramatic' (p. 192). In economy, for instance, we may observe how 'goods and services "live" in niches created by other goods and services' (p. 217). As in biological evolution, then, some of these products manage to become more or less immune to changes in the evolutionary process while others become extinct. The relationship between biological and technological processes, usually understood in terms of an opposition, is thus examined and questioned through the introduction of two concepts that aim to make the opposition less sharp. In order to further foreground the similarity between processes in these domains, Kauffman introduces yet another new term, 'technosphere' (p. 217), as a conceptual counterpart to the more familiar notion of the biosphere. The analogous form of these two concepts suggests that fundamentally similar laws of evolution govern them; note how alliteration in the claim 'Tissue and terracotta may evolve by deeply similar laws' (p. 192) also points to similarity between these processes.

The reconciliation of biological and cultural kinds of evolution is important by forming an argumentative basis for Kauffman's societal vision. 'The edge of chaos', he muses, 'may even provide a deep new understanding of the logic of democracy' (p. 28). Elaborating on this possibility, he proceeds to draw an analogy between self-organization in natural systems and the process leading to democracy:

> [The] seemingly haphazard process of [solving problems created by conflicting interests] also shows an ordered regime where poor compromises are found quickly, a chaotic regime where no compromise is ever settled on, and a phase transition where compromises are

> achieved, but not quickly. The best compromises appear to occur at the phase transition between order and chaos. (p. 28)

The passage shows how Kauffman bases the analogy on a double hierarchy argument: the model of the process leading to democracy is juxtaposed with natural processes heading incrementally towards the transitional zone between order and chaos. Also in this respect we may observe how Kauffman's vision seeks to redefine Darwinism and its implications: instead of a society based on the idea of the survival of only the fittest, Kauffman finds in the edge of chaos an apt model for tolerant pluralism that gives all individuals 'a chance to prosper' (p. 28) on the basis of the 'possibility that our social institutions evolve as expressions of deep natural principles' (p. 304).[15]

As indicated by some of the previous passages, Kauffman's vision of a society at the edge of chaos clearly foregrounds a strong sense of collective participation. Stylistically speaking, he invokes it through the very simple means of repeating the first person plural pronoun. Although Kauffman uses this technique throughout his book — and especially when discussing the philosophical implications of self-organization — one example will suffice. Pointing to the inherent unpredictability of chaotic systems, he mentions the need to approach nature with respect:

> If we find renewed concern about the untellable [*sic*] consequences of our best actions, that is wise. It is not as though we could find a stance with either moral or secular certainty. We make our worlds together. All we can do is be locally wise, even though our own best efforts will ultimately create the conditions that lead to our transformations to utterly unforeseeable ways of being. We can only strut and fret our hour, yet this is our own and only role in the play. We ought, then, play it proudly but humbly. (p. 303)

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[15] For critique of Kauffman's idea of democracy as a natural outcome of evolutionary processes, see Benjamin J. Robertson, 'On Moral Science: The Problematic Politics of Stuart Kauffman's Order', *Configurations*, 12.2 (2004), 287–312.

By emphasizing the sense of collective action, the anaphoric repetition of *we* in passages such as this does much to embody the underlying ethic of *At Home in the Universe*. As in Lynn Margulis and Dorion Sagan's *What is Life?*, analysed in the next chapter, it is an ethic that seeks to re-evaluate the place of humankind in the universe. Kauffman argues that even though we are at home on the Earth, we should not think of ourselves as having a special status in comparison to other forms of life. On the contrary, our increasing understanding of self-organization and complexity implies a need to modify the current, anthropocentric worldview: 'We begin to know that proud humankind is still another beast, still embedded in nature, still spoken for by a larger voice' (p. 303).

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To conclude, much of the popular science writing analysed above uses figurative language to reconcile various kinds of dichotomies, at the same time establishing a link between nature and humankind. Ilya Prigogine and Isabelle Stengers's *Order out of Chaos* and Prigogine's *The End of Certainty* use the strategy of subjecting opposite concepts to all-inclusive third terms in order to make irreversibility the common ground of humankind and the world, as well as of determinism and indeterminism. Prigogine also relies on other figures that epitomize the same reconciliation: while his incremental series suggest that the arrow of time pierces through all levels of physical existence, the antimetaboles in the quotations from Nabokov and Borges emphasize the dynamic role of time in defining human reality. In the same way, Paul Davies in *The Cosmic Blueprint* makes chaos an umbrella term that links chance and necessity while using antithetical formulations to establish dynamic non-linearity as a fundamental feature of the universe. Davies's argument for adopting a holistic view in turn employs incrementum as the basis of a double hierarchy argument that juxtaposes levels of description in mathematics on the one hand, and in physics and biology on the other. Finally, Stuart Kauffman in *At Home in the Universe* uses a variety of figures for various argumentative purposes: he employs antimetabole to link concepts such as self-organization and natural selection, and the whole and the part; antithesis to create slogan-like statements about the role of chance and unpredictability; umbrella terms to show the similarity of co-evolutionary processes; incrementum and double hierarchy argument to reconcile the relationship between chaos and order; and repetition to portray autocatalytic processes and to epitomize the ethos of his vision.

3.2.2 The Part and the Whole: Holism, Unpredictability, and the Question of Determinism

Let us now turn to look at how contemporary novelists have appropriated the terminology and ideas of chaos theory and complexity. Like the new physics yet only more so, chaos theory has had an impact not only on scientific worldview but also on artistic imagination. Because of its applicability to events in the realm of the macroscopic, it has proven very attractive for artists searching for new conceptual tools for the exploration of the relationship between the individual and the world. Merja Polvinen neatly summarizes the main reasons for the charm of chaos theory as follows:

> Why should a mathematical theory that describes the behaviour of turbulence be able to explain the way we experience and gather knowledge about the world? The answer lies in the inherently ambiguous nature of both the laws of chaos and our experience of the world. On the one hand, we see ourselves as coherent selves, living our lives in a fairly straightforward fashion. On the other, we are simultaneously aware of a bombardment of an infinite variety of sense impressions, memories, feelings and concepts from which that coherent experience is selected and formed. Similarly, chaos theory describes a reality which is too fragmented, too variable and too unpredictable to calculate, but which nevertheless displays startling coherence and harmony. (p. 49)

This summary offers an explanation to why chaos has become so widespread as a cultural metaphor and symbol. Given the similarity between the human experience of the world and the way in which the world is described in the models of chaos theory, it is not surprising that numerous literary works that employ terminology familiar from the studies of chaotic and complex phenomena have appeared in the last two decades. Although there are many aspects to the use of chaos in the arts, what is characteristic of such literature is that it uses chaos as a distinctive thematic element that foregrounds the complex and unpredictable nature of the relationship between human beings and reality (Polvinen, p. 51). More specifically, Polvinen argues that there are five thematic main groups in literature inspired by chaos theory: the relationship between humankind and nature, the issue of human control over nature, the relationship between fate and free will, the importance of holistic thinking to the understanding of life, and the nature of human perception (pp. 51–53).

The notion that chaos theory can encourage us to adopt a holistic outlook on life is evident in the first novel discussed in this subchapter: the American writer Connie Willis's *Bellwether*, which, like Stuart Kauffman's *At Home in the Universe*, examines the relationship between chaotic systems and cultural trends, suggesting that both evolve according to similar laws. The protagonist of Willis's novel, Sandra Foster, is a sociologist who studies fads in a large corporation. She is particularly interested in their sources, especially as they seem to emerge 'for no apparent reason'.[16] The plot also features Sandra's developing relationship to the chaos theorist and co-worker Bennett O'Reilly, whose ideas eventually help Sandra understand how large cultural phenomena are born as a result of a host of small events, so that it becomes impossible to assign a single source of origin for them. Moreover, *Bellwether* draws an analogy between chaos and human relationships: the relationship of Sandra and Bennett emerges as a result of a series of haphazard events that eventually reaches the ordered state of unification, as the metaphorical chaos surrounding the relationship reaches a new level of organization.

In the context of our discussion on the common concerns of popular science writing and fiction, it should be noted that by juxtaposing chaos theory and cultural phenomena, Willis focuses on one of the major dichotomies discussed in the work of Prigogine and Stengers and Kauffman: the relationship between humankind and nature. The exploration of this relationship mainly concerns the shared topics of knowledge and, to some extent, identity. As discussed above, the argument of Prigogine and Stengers concerning this particular dichotomy is that with its insistence on the reversibility of temporal processes, the worldview of classical physics has to a considerable extent contributed to humankind's alienation from nature, while for Kauffman Darwinism's emphasis on the contingent has similarly alienated humankind from the world. Although Willis's novel does not deal with

[16] Connie Willis, *Bellwether* (New York: Bantam Books, 1996; 1997), p. 8. Further references to this book are given in parenthesis.

the theme of alienation, it does participate in the discussion about the relationship of humankind and the world by suggesting that the scientific understanding of nature is directly linked to humankind's understanding of itself, foregrounding the idea that scientific models of nature can be used metaphorically to describe things that belong exclusively to the human realm of experience (Polvinen, p. 51). Since chaos theory allows us to detect an ordered pattern, a strange attractor, beneath the surface of chaotic activity, it is possible to make the highly appealing suggestion that similar patterns in human life are indicators of life's purposefulness. In other words, chaos is a meaningful phenomenon from the viewpoint of life in the macroscopic world. The novel thus emphasizes the role of chaos as a positive force in life: like the highly organized systems studied by chaos theory, fads, scientific discoveries, and relationships emerge as a result of an essentially creative process that has its roots in both chance and determinism.

This sense of meaningfulness has much to do with the way in which the novel approaches the question of holism. As all the popular books discussed above argue, one of the significant contributions of chaos theory to the philosophy of science is the idea that systems exhibiting chaotic behaviour cannot be reduced to their basic constituents without distorting our view of how the systems function. This makes chaos theory and studies of complexity characteristically synthetic or holistic sciences, as they aim to see how the interaction of the parts contributes to the functioning of the whole. In *Bellwether* the importance of seeing life from a holistic viewpoint is suggested by Sandra's comparison between the origins of fads and rivers, as she ponders on the problem of tracing the sources of the former. 'It's almost impossible to pinpoint the beginning of a fad', she notes, 'By the time it starts to look like one, its origins are far in the past, and trying to trace them back is exponentially harder than […] looking for the source of the Nile' (p. 3). Through repeated references to major rivers around the world — the Nile, the Thames, the Colorado River, the Loue, and the Lena — the image of the river becomes a symbol for a whole composed of interconnected parts:

> Rivers are not just wide streams. They are drainage basins for dozens, sometimes hundreds of tributaries. The Lena River in Siberia, for example, drains an area of over a million square miles, including the Karenga, the Olekma, the Vitim, and the Aldan rivers, and a thousand smaller streams and brooks, some of which follow such distant, convoluted courses it would never occur to you they connected to the Lena, thousands of miles away. (p. 95)

The idea of a large river as a drainage basin of small rivers foregrounds the suggestion that because we do not really have knowledge of the whole river until we learn how its constituent parts interact, the study of its individual tributaries cannot convey a comprehensive picture of the whole. Reflecting the reciprocal logic of Kauffman's antimetabole that epitomizes his view of the relationship between the whole and its parts, the passage implies that since rivers and tributaries are thus inseparable from each other, it is clearly impossible to isolate one single main source. In this way, the haphazard collection of tributaries, streams, and brooks symbolizes the chaotic state of the system before it reaches a higher level of organization: the river. (The notion of chaos as the predecessor of order is evident not only in the novel's imagery but also in its structure: as the suggestive titles of the parts — 'Beginning', 'Bubblings', 'Tributaries', 'Rapids', and 'Main Channel' — indicate, the structure of the narrative models the structure of a metaphorical river.)

Sandra's research into the origin of fads reveals that cultural systems tend to behave in the manner of nature's chaotic systems. Like rivers, they flow through culture, functioning as 'a facet of the chaotic system of society' (p. 107). Instead of a single main source, there is often a large number of small cultural tributaries that are all equally important in the birth of a fad. For instance, among the causes for the fad of hair-bobbing Sandra lists ‘female equality, bicycling, a French fashion designer named Poiret, World War One, and Coco Chanel’ (p. 89). In this way, the novel suggests that the same kinds of mathematical models Sandra creates to describe the behaviour of natural phenomena can be extended, as it were, to processes peculiar to culture. Thus, *Bellwether* establishes a parallel between two types of knowledge, scientific and cultural, and suggests that our knowledge of chaotic natural systems can shed light on similarly chaotic cultural phenomena, the origins of whose products seem to defy simplistic causal explanations.

Another link that the novel draws between natural and cultural phenomena is the one between chaotic systems and mental processes, since for Sandra rivers, fads, and scientific insights are all examples of wholes that emerge from a multitude of sources. Noting that the link between chaos and important scientific discoveries was first suggested by Henri Poincaré, she describes how the solution to a major scientific problem became crystallized in Poincaré’s mind while stepping onto a bus:

> The chaotic circumstances — Poincaré’s frustration with the problem, his insomnia, the distractions of packing for a trip, the change of scenery — created a far-from-equilibrium situation in which unconnected ideas shifted into new and startling conjunctions with each other and tiny events could have enormous consequences. (p. 215)

Just as in the river analogy, the chaos of the individual parts gives rise to an integrated whole, as the chaos surrounding the philosopher’s mind leads into an insight. This idea is also evident in the portrayal of the situation leading to Einstein’s groundbreaking work. ‘He discovered relativity’, Sandra notes, ‘while he was working in a dinky patent office, full of papers and contraptions. When he tried to work at home, it was even worse. Wet laundry hanging everywhere, a baby squalling on one knee, his first wife yelling at him' (p. 241). Both examples foreground the idea that instead of merely reducing complex systems to their constituent parts, they need to be studied on the basis of the interaction of the parts.

Thirdly — and this is where the novel most explicitly creates a link between natural systems and everyday life — the process leading to the love affair between Sandra and Bennett is described in terms of chaotic behaviour stabilizing into a new kind of order. The chaotic phase of the affair is initiated by the company secretary Flip, who fails to deliver a package to the right person and in doing so inadvertently launches a chain of events that has many unpredictable consequences. During this phase everything Flip does continues to increase the amount of chaos in Sandra's life: she lies to Bennett that Sandra is already engaged, fails to take photocopies of important pages for a meeting, and so forth. Eventually the process culminates in Flip unconsciously helping a flock of sheep that Bennett studies for scientific purposes leave their paddock — the bell-wether of the novel's title is the leading sheep of the flock that learns to open the paddock gate by observing Flip — and enter the corporation's main building, thus taking chaos to the heart of organized scientific and commercial activity. In short, with its increasingly chaotic events, this process resembles much the incremental series that Kauffman uses to depict the heading of ordered systems towards the edge of chaos.

As in the case of other types of complex phenomena, the sheer number of factors involved in the relationship makes it impossible to separate the irrelevant from the relevant. Sandra observes that the chaotic events of her life are continuously 'iterating and reiterating and leading inevitably to an outcome' (p. 195), although the precise nature of that outcome is impossible to predict. The novel therefore suggests that it is possible to see similar patterns in both nature and the lives of individuals, even though it might be impossible to clearly distinguish between the important and the unimportant factors. In order to fully understand natural systems as well as cultural and human phenomena, then, one must study them through a holistic framework that, unlike the reductionistic view, allows us to see the big picture rather than a mass of meaningless details: although reduction is necessary for the identification of the individual constituents, it is the study of their relationships that ultimately reveals us the true nature of the whole (Polvinen, pp. 52–53). This recalls Davies's use of double hierarchy argument about how complexity cannot be reduced downwards: with their interconnected events and levels, both the pattern of Sandra's life and the incremental series in Davies's argument repeat themselves in the fashion of fractal shapes, creating novel structures.

The idea that it is possible to see a pattern behind seemingly unconnected things by adopting a holistic outlook is linked to the question about the meaning of the pattern. When Sandra feeds the various events leading to the birth of fads into her computer, she sees that they form a strange attractor, an indication of order within chaos: the 'layer on layer of events feeding back into each other […] sprang suddenly into a new design. A beautiful, elaborate structure, vivid with radical red and cerulean blue' (p. 236). For Sandra, the pattern is an indication of purpose, as all the parts appear to contribute to the outcome in a meaningful way. Seen from the holistic viewpoint, the extraneous noise that is introduced into Sandra's life as a result of Flip's incompetence as a secretary is a fundamentally creative force that produces new order. Chaos is thus a deeply meaningful phenomenon, even if its purpose can be revealed only retrospectively, as Sandra notes after having become aware of the pattern. 'I had been wrong', she notes, 'The *i* on [Flip's] forehead didn't stand for *incompetence* or *itch*. Or even *influence*. It stood for *inspiration*' (p. 236; emphases original). Just as Prigogine and Stengers with their arrow of time and Davies with his blueprint metaphor, then, *Bellwether* sees chaos as a fundamentally creative phenomenon, in which the increase of entropy signals meaningful novelty and beginning instead of meaningless disorder and ending.

The question of purpose and meaning of chaos is in turn closely linked to the problem of free will. Significantly, both bell-wethers in the novel, Flip and the sheep that leads the flock, are described as unaware of their roles as agents of chaos. Sandra notes they are 'moved by feelings they weren't aware of, by forces they didn't understand. Right straight into the river' (p. 204), a comment suggesting that humans do not really know the motivations behind their own actions. At the same time, however, the novel does suggest that as humans become more and more familiar with the mechanisms of chaos, the mechanisms may be consciously utilized in creative ways. 'So many discoveries are made by scientists outside their field', as Sandra notes at the end of the novel, 'Which is why you […] choose people working outside their field, because you know how it worked, even if you didn't know why' (p. 242). In this way, the novel captures the ambiguity that surrounds the implications of chaos theory for humankind: although characters both unconsciously initiate and experience the unfolding of chaotic patterns, the novel at the same time hints at the possibility of scientific knowledge helping humankind achieve control over processes that are seemingly uncontrollable. As in the case of the new physics, then, science is simultaneously seen as a source of power and a limitation: it gives humans the opportunity to control nature while exposing a fundamental lack in our knowledge of ourselves.

* * *

The issue of holism is also present in the American science fiction writer Kate Wilhelm's *Death Qualified*. Wilhelm's story is a traditional murder mystery, in which the protagonist, an ex-lawyer named Barbara Holloway, defends Nell Kendricks, a woman accused of killing her husband. During her investigations Barbara finds out that prior to his death, the victim had been subjected to psychological testing that aimed at the alteration of his perception: a chaos theorist had used fractal images to make his subject 'see the world the way it really is'[17] — that is, to experience reality in a way that perception is as little as possible conditioned by preconceived ideas and beliefs (Polvinen, p. 53). In this way, the novel examines the relationship between humankind and the world, emphasizing the role of the mind as the main connecting factor between the two.

Like *Bellwether*, *Death Qualified* uses images associated with chaos theory in order to portray the development of the protagonist's inner life as well as her relationship to the world. For instance, the ubiquitous image of fractals forming repetitive, self-similar patterns at different scales is evident in the narrator's description of Barbara watching the flow of a river: in her mind she compares the movement of water with 'ever-rising fugues, repeating a theme without end, varying it slightly each time, but always the same theme' (p. 141). Indeed, the narrator's descriptions of natural scenery often employ imagery that makes sameness and difference the complementary elements of a continuous pattern: 'Trees grew, died, fell; and new trees rose, always the same in the midst of change' (p.

[17] Kate Wilhelm, *Death Qualified: A Mystery of Chaos* (New York: Fawcett, 1991), p. 338. Further references to this book are given in parenthesis.

431). The patterns of nature's processes are in turn reflected in the life of the protagonist, suggesting an analogy between the two:

> The wheel turns, she thought, and we're all on it. It turns, goes this way and that with a curious wobble, and sometimes you think it's taking you to someplace brand-new and wonderful, everything looks fresh and interesting, and then with the next turn, you're back at the same place. Everything different, everything the same. Different details, different cast of characters, and the same. Ever-rising music, ever-flowing river, ever-changing people; all the same forever and ever. (p. 143)

The passage uses an image of a wheel to link the idea of fractal self-similarity to a distinctively cyclical view of time, thus strengthening the link between the processes of nature and human life. What is more, the synoeciosis-like juxtaposition of the adjectives *different* and *same* suggests that human life is essentially a fractal pattern characterized by the co-existence of opposite elements.

The link between nature and human life is also suggested by the idea that although the notion of life as a pattern of difference and sameness might imply certain predictability, the patterns of both nature and human life are nevertheless fundamentally unpredictable. This can be seen, for instance, in the way in which the narrator describes her client's trial:

> Nothing unforeseen, everything in order, as predictable as movements in a stately dance in rhythm with unheard music. What no one could foretell was when the music would become discordant, when a false note would break the rhythm, or even if that false note had already been played, if the ripples were already forming, the pattern already altered irretrievably. (p. 186)

Describing the progress of the trial as a musical performance, the passage alludes to the behaviour of chaotic natural phenomena (the word *ripples* referring to disturbances on the surface of water). It suggests that in seeming order, there is inherent unpredictability whose existence makes it impossible to predict the direction in which the system is heading.

Hence, the novel depicts the pattern of human life as a mixture of deterministic and indeterministic elements comparable to processes found in nature — note how the same idea is evident in Prigogine's reconciliatory portrayal of determinism and indeterminism as interlinked concepts, as well as Davies's blueprint metaphor.

However, the most important image that links nature and human life in *Death Qualified* is the strange attractor, an equation or fractal set describing a complex pattern in a chaotic system, which the narrator employs to describe the effects of the actions taken by the novel's characters. Before he is killed, Lucas Kendricks, the murdered husband, manages to escape from the place where he is being subjected to psychological testing; the novel presents the escape as a crucial event, from which all the other events in the story follow. The narrator describes the effects of Lucas's escape on the scientists in the project as follows:

> They had withdrawn into their separate orbits again, the three who remained, but there were after-effects of the perturbation of a wild player who hadn't known his orbit, his rightful place, who had swung erratically back and forth, first into this orbit, then that, and even though he was gone, his tracks remained, distorting the hard lines of separation everywhere he had been, and there were no boundaries, no sharp divisions. Where he had been there was chaos. (p. 150)

Wilhelm models the behaviour of the scientists and Lucas in terms of a strange attractor, suggesting that the situation is comparable to the one in a system approaching the state of thermodynamic equilibrium. Like the comparison between the court case and a musical performance, the analogy drawn between Lucas's escape and a system heading towards chaos foregrounds the crucial role played by unpredictability. He knocks the system off balance from the inside by stealing the information concerning the project, and this has consequences that affect the other characters in unpredictable ways. In the same way, after having been instructed in the basics of chaos theory by the mathematician Mike Dinesen, Barbara perceives a structural similarity between a strange attractor and her case:

> She had learned that a strange attractor was not simply a point but could also be a pattern that repeated over and over, always similar, never exactly the same, and she felt that the pattern of those scientists circling around Lucas, the dead boy and the dead Frobisher, all made up a strange attractor. […]. She, Barbara, was part of the pattern, she acknowledged, although she could not say how or why. (p. 178)

This passage reveals a characteristic shared by the novel's main characters: they are all caught, as it were, in self-similar patterns and thus cannot perceive the whole formed by the various events around them — a situation much like the one in which the characters of Connie Willis's *Bellwether* find themselves. As a lawyer Barbara is especially affected by this dilemma, as her task demands that the jury be made understand how and why the individual events contribute to the overall picture.

The problem of grasping the whole in all its complexity is also approached through images suggesting another fundamental characteristic of chaotic systems: turbulence. Mike Dinesen, who helps Barbara solve the case and eventually begins a relationship with her, becomes affected by the same fractal images that were used on Lucas, consequently confronting unpredictability in the form of unmediated sensory data: 'The whirlpool will throw me out sooner or later, the synapses will reconnect in a new pattern, the turbulence will end and there will be different linkages, but what kind, what will they mean?' (p. 385). Likening the disorder of Mike's consciousness to a chaotic natural phenomenon, the passage draws attention to the role of chaos as a source of novelty whose form is impossible to predict. Like the dinosaur island in Michael Crichton's *Jurassic Park*, discussed below, both human consciousness and the murder case are hence portrayed as metaphorical complex systems whose apparent simplicity obscures their complexity. In the latter case, although Nell Kendricks seems to many as the most likely candidate for the murderer, the link between the actual perpetrator, an unsuspected logging company worker who kills Lucas as a means of making him appear responsible for the murder of a hitchhiker committed by the worker, and the case is hidden behind a complex network of other links. This suggests that as observers we are incapable of making totally accurate predictions because of the complexity of the interaction between the various parts of the whole.

As in Willis's novel, the adoption of a holistic view is connected to the discovery of a deep sense of meaning in the world. In order to teach Barbara to see the world from a new angle, Mike Dinesen shows her an image of a tree and explains how it models the idea of self-similarity. 'Start with the whole tree', he instructs her, 'and then the single leaf, and now the veins in the leaf, and the root system, all similar. […]. Nothing's isolated, nothing. It's all connected' (p. 163). In terms of the passage's figurative language, Wilhelm uses a descending incrementum to emphasize the notion of similarity across the scale. For the narrator, however, the idea of self-similarity is primarily a means of describing the meaningful quality that individuals link to the patterns of their lives:

> *And just what do you think you're doing?* she demanded of herself, standing at the bathroom sink holding a bar of soap. But she knew, and so did Mike. They would have coffee, go out to dinner, come back here, and go to bed together. It had been inevitable from the moment he had laid his hand on her shoulder because it was a natural thing to do, and she had accepted the naturalness of the act, from the moment he said her name on the library stairs, from the moment she dialed his number, from the moment she heard her father's voice on her answering machine in Phoenix, from the moment of her birth. It had been inevitable. (p. 164; emphasis original)

This passage shows how Wilhelm's novel uses chaos theory to portray life as a mixture of deterministic and indeterministic elements. In Barbara's case determinism in fact manifests itself as a certain kind of fatalism — it is only our incomplete knowledge that obscures the fact that everything is predetermined. At the same time, the notion of predetermination carries with it a pronounced sense of meaningfulness, as the protagonist through her adoption of a holistic outlook understands that the apparent chaos hides order in the form of a pattern. Hence, it is suggested that only by understanding how all its details are connected to each other as a whole are we able to make sense of chaos in human life and that it is this sense of underlying order and meaning that the protagonist sees as fate.

With her newly found understanding of holism, Barbara is able to regard not only her own life but also the world from a new perspective. This is evident in the portrayal of her viewing natural scenery in distinctively holistic terms:

> She thought of the great heart of the Earth pumping its life-giving water in tiny rivulets that appeared only during the rainy season, and then joined the bigger creeks, like Halleck Creek, which rushed to the McKenzie River, which in turn joined the Willamette, and then the Columbia and at last made the tremendous flood that fed the great ocean. (p. 291)

This rather new-ageish passage — the heart metaphor clearly anthropomorphizes the planet — uses a gradatio-like structure that in the fashion of Kauffman's gradatio describing the interconnected parts of autocatalytic processes conveys a sense of interconnectedness between the various parts of the whole. Like the similar image in *Bellwether*, it symbolically foregrounds the idea that everything in the world is connected, thus locating the model for the interconnectedness of human life in nature. In this sense, the notion of nature and human life mirroring each other is marked especially in the way in which Barbara's relationships to other characters are described. Thinking about fractal shapes with their same-different patterns, Barbara notes that 'she and her father were segments of one of the patterns, swirling about each other, touching, withdrawing, flying off in opposite directions, returning' (p. 361). Her relationship to Mike is portrayed in similar terms: 'They kept meeting on new grounds, the same two people creating ever-new patterns' (p. 413). Barbara's observations reflect the idea that as parts of such patterns, individuals are not separate from but connected to each other through the 'invisible links' of 'love, hatred, jealousy, greed' (p. 362), thus forming interconnected wholes similar to the ones in nature.

* * *

That chaos theory forces us to look at nature holistically is also the underlying idea in Michael Crichton's *Jurassic Park.* Crichton's bestseller is an adventure story about a zoo-cum-amusement park built on a Central American island whose inhabitants are genetically engineered dinosaurs. The story begins with a description of humans being attacked by miniature dinosaurs in Costa Rica and the attempts of baffled scientists to discover the origin of the creatures. The explanation for the mystery begins to surface when it is revealed that the owner of the park, the ambitious businessman John Hammond, has become worried about the possible risks that the animals might pose to visitor safety and investments, consequently assembling an interdisciplinary team of experts to assess the seriousness of the issue. Predictably, the control system of the park turns out to be faulty — some of the animals have escaped from the island to the mainland in Costa Rica — and the dinosaurs begin to wreak havoc on each other as well as the humans trying to control them.

Although the disastrous confrontation of nature and high technology in the novel obviously functions as a critique of biotechnology and the increasing commercialization of genetic engineering — the introduction to the story, 'The InGen Incident', features a report on the activities of Hammond's company that criticizes the alliance of science and capitalism in molecular biology — Crichton employs chaos-theoretical ideas to examine whether it is possible to use high technology to control the complex systems of nature (Polvinen, p. 51). In this way, the novel discusses the consequences of the attempt of trying to dominate systems that are inherently unpredictable and suggests that instead of taking such a hubristic approach, humankind should learn to cultivate a holistic attitude towards nature — an idea that links the novel to Stuart Kauffman's discussion on the ethical aspects of scientific knowledge.

Like *Bellwether*, *Jurassic Park* uses the idea of systems becoming increasingly chaotic not only as a thematic element but also as a means of structuring the story. The events progress through six 'iterations' (main chapters) during which the team discovers answers to the mysteries surrounding the park, and the park personnel on the island are little by little forced to abandon their attempts of controlling the dinosaurs — this obviously reflects the park's change from a stable organized system to an unstable chaotic one. The epigraph to the first iteration, which is a quotation from the team's chaos theorist, the mathematician Ian Malcolm, states that 'at the earliest drawings of the fractal curve, few clues to the underlying mathematical structure will be seen',[18] pointing to the fact that at this point we do not yet know why people on the coast of Costa Rica are being attacked by the miniature

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[18] Michael Crichton, *Jurassic Park* (London: Random House, 1991), p. 9. Further references to this book are given in parenthesis.

dinosaurs. As the second iteration begins, the delicate balance of the ecosystem of the park is already on its way of becoming unstable (another epigraph quoting Malcolm predicts that 'sudden changes may appear' (p. 31) at this point), and the team learns that Hammond has succeeded in cloning prehistoric animals. Finally, during the rest of the iterations, the team learns more about the behaviour of the dinosaurs ('Details emerge more clearly as the fractal curve is redrawn' (p. 83)), the amount of chaos in the island still increases, and the system eventually goes beyond recovery, as all control is lost. In this way, then, the structure of *Jurassic Park* reflects the idea that human attempts at the complete mastery of nature are impossible because it is impossible to accurately predict how complex systems will develop over long periods of time. Echoing Kauffman's incremental series, the plot thus develops step by step towards the edge of chaos.

In the same way, the content of the novel emphasizes the fundamentally unpredictable nature of chaotic phenomena, as Ian Malcolm's lecture-like explanations of his field of expertise show. At the heart of Malcolm's argument is the idea that we can understand the basic processes of everyday life through mathematical modelling of complex systems. Explaining to the palaeontologist Alan Grant the relationship between the whole and its constituent parts, he draws attention to their structural similarity:

> When you study fluctuations in cotton prices, you find that the graph of price fluctuations in the course of a day looks basically like the graph for a week, which looks basically like the graph for a year, or for ten years. And that's how things are. A day is like a whole life. You start out doing one thing, but end up doing something else, plan to run an errand, but never get there. [...]. And at the end of your life, your whole existence has that same haphazard quality, too. Your whole life has the same shape as a single day. (p. 171)

Malcolm's analogy between cotton market fluctuations and the course of an individual's life suggests that both are basically fractal patterns, whose essential characteristic is self-similarity. Underlying the self-similarity is in turn turbulence that in the form of continuous fluctuation shapes both the part and the whole. Thus, like Kate Wilhelm's *Death Qualified*, *Jurassic Park* makes turbulence a metaphor for the inherent unpredictability of everyday existence. In terms of our discussion of the relationship between the whole and its parts, then, it is not surprising that many seemingly insignificant events in the novel turn out to have dramatic or catastrophic consequences. For instance, Dr Wu, the geneticist responsible for creating the park's animals, uses amphibian DNA to construct dinosaurs without realizing that it changes the sex of some of them from female to male, thus allowing the dinosaurs to breed (Wu had originally planned to make all the dinosaurs female in order to prevent them from breeding). Similarly, Hammond had refused to pay Dennis Nedry, the park's computer expert, for the extensive modifications he had made to the computer system used for controlling the dinosaurs, resulting in Nedry's becoming a spy for a rival company interested in the commercial aspects of gene modification. In order to avoid getting caught stealing Wu's dinosaur embryos, Nedry jams the computer system, causing the fences that restrict the movement of the dinosaurs to malfunction with disastrous results.

In other words, much of the novel's critique of what it sees as the dominant attitude of contemporary (Western) science stems from the idea that ethically responsible science can only emerge through the cultivation of holistic thinking. This is evident in the way Crichton juxtaposes the views of Malcolm with those of Wu and the park engineer John Arnold in order to contrast the holistic view of the former with the myopic vision of the latter. 'They're both technicians', Malcolm says, 'They don't have intelligence. They have what I call "thintelligence." They see the immediate situation. […]. They don't see the surround'

(p. 284). Hence, voicing its own position through the character of the chaos mathematician, the novel suggests that their short-sightedness and hubris go hand in hand. For instance, when one of the park personnel manages to temporarily immobilize a Tyrannosaurus Rex spreading mayhem in its surroundings, Arnold is depicted acting characteristically nonchalant, as he uses the control system to trap the animal: 'He pushed back in his chair, and grinned as he lit a final cigarette and crumpled the pack. That did it: the final step in putting the park back in order' (p. 299). Moments later, however, a power failure hits the park's power system, enabling the escape of equally voracious velociraptors. It is obvious that this happens because of Arnold's incapability of seeing the big picture. Because he is so focused on finding the Tyrannosaurus, Arnold does not notice that the security system of the park is running on insufficient auxiliary power. As Hammond later notes, Arnold 'hadn't been organized, and he had missed things. Important things' (p. 380). Wu's biggest failure, in turn, is that he engineers dinosaurs, even though he knows that it is 'impossible' (p. 333) to predict their behaviour.

Closely linked to these considerations is a clash between two opposing views of the park as a system. While Hammond repeatedly emphasizes the simplicity of the idea behind Jurassic Park, Malcolm argues that behind the apparent simplicity of cloning DNA and controlling the animals is the complexity of factors more numerous than Hammond and the others are capable of perceiving (p. 305). While Malcolm's knowledge of chaos theory allows him to see that 'simple systems can produce complex behaviour' (p. 76) that is characterized by inherent unpredictability, Hammond erroneously believes that unpredictable events, such as dinosaurs escaping their confinement or mating, can be controlled by keeping the system — the island — isolated from its surroundings. Hence, in

Malcolm's holistic view, '"nature" is in fact a complex system of far greater subtlety than we are willing to accept' (p. 93), whereas Hammond's park represents a simplified model of the real thing with its unrealistic ideal of complete isolation.

Through the portrayal of chaos theory as a distinctively holistic science, then, *Jurassic Park* attributes to it the humility and ethical awareness that genetic engineering lacks. With its attention to the interaction of the whole and its constituent parts, including the idea that humankind is inseparable from other species and nature, chaos theory in the novel embodies values that technological advance seems to have neglected. 'When the hunter goes out in the rain forest to seek food for his family,' Malcolm asks, 'does he expect to control nature? No. He imagines that nature is beyond him. Beyond his understanding. Beyond his control' (p. 349). The inevitable destruction of the park can thus be understood symbolizing the end of a particular type of scientific mentality: with its short-sighted focus on gaining profit, genetic engineering represents an outlook blind to its own shortcomings. In contrast, with its emphasis on unpredictability and holism, chaos theory represents a humbler attitude towards nature. In this way, the dichotomy between the two views echoes Kauffman's antithetical statements concerning the limits of human knowledge and the predictability of natural processes — instead of aiming at global mastery, humans should strive to respect nature through local understanding of nature.

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The interlinked issues of prediction and control are studied from a different angle in William Gibson and Bruce Sterling's *The Difference Engine*. Consisting of three intertwined strands, the story writes an alternative history of the mid-Victorian England by imagining what that society would have been like had the industrial revolution been powered by technology more sophisticated than was the case. The protagonist of the first strand, the daughter of a Luddite agitator called Sybil Gerard, who lives an adventurous life as a high-class prostitute, comes into possession of a box containing punch cards for the so-called difference engine, a primitive computer modelled after the nineteenth-century mathematician Charles Babbage's mechanical computer, which was designed to accurately calculate mathematical and astronomical tables. (Although Babbage's difference engine could not be built in the lifetime of its inventor, in the novel difference engines exist, and the Victorians use them to build steam-powered machines that closely resemble their twentieth-century counterparts, such as 'gurneys' (cars), 'kinotropes' (cinematographs), automatic weapons, 'typing engines' (typewriters), calculators, and so forth.) The box then finds its way into the hands of the protagonist of the second strand, the palaeontologist Edward Mallory, who has recently achieved considerable scientific fame by discovering the bones of a brontosaurus in North America. From this point on, the second strand follows Mallory's attempts of trying to solve the mystery of the cards and his struggle against various instances that are interested in exploiting them for their own criminal ends. The third strand in turn focuses on the detective and governmental spy Laurence Oliphant, who meets Sybil Gerrard in France, thus linking the beginning and the end of the story. Finally, there is a separate section, 'Modus', which is basically a collection of miscellaneous documents, such as passages from the writings of Charles Babbage, letters by contemporary politicians, a John Keats interview, song lyrics, a poem, and so forth. More importantly, however, the final section reveals the nature of the punch cards: containing information for the so-called Modus Programme, they were designed by their creator, Ada Lovelace (Ada's father, Lord Byron, is in the novel the Prime Minister of England), to drive the difference engine by using the principle of self-referentiality, thus functioning as a metasystem for mathematical calculations.

In terms of the novel's examination of the issue of control, one of its notable features is that just as the other writers discussed in this subchapter, Gibson and Sterling establish different kinds of analogies between nature and human life. The first of them illustrates the functioning of the human mind by suggesting that both nature and mind feature processes that can be termed chaotic. For instance, the statesman and novelist Benjamin Disraeli, who is one of the famous Victorian personages appearing in the novel, explains the writing process to Mallory as follows:

> There are tumults of the mind, when, like the great convulsions of nature, all seems anarchy and returning chaos: yet often, in those moments of vast disturbance, as in the strife of nature itself, some new principle of order, or some new impulse of conduct, develops itself, and controls, and regulates, and brings to an harmonious consequence, passions and elements which seem only to threaten despair and subversion.[19]

Note how Disraeli's description of the creative process is reminiscent of the protagonist's musings on scientific genius in Willis's *Bellwether*. In addition to presenting chaos as a force capable of innovation, the passage foregrounds the notion of chaos as a self-sustaining phenomenon that creates order spontaneously.

However, the second type of analogy suggests that it is not only the human mind but also society that functions and evolves according to the laws of chaos and complexity

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[19] William Gibson and Bruce Sterling, *The Difference Engine* (London: Gollancz, 1990; 1996), p. 175. Further references to this book are given in parenthesis.

(Polvinen, p. 51). Through a process converse to that described in the above quotation, order gives way to chaos in Gibson and Sterling's portrayal of London's incremental descent into disorder. Mallory observes that the inhabitants of London are 'like a gas, […] like a cloud of minute atomies. The bonds of society broken, they had simply flown apart, like the perfectly elastic gassy spheres in Boyle's Laws of Physics' (p. 219). Following these similes, Mallory uses another one to compare the disorder of the great city to drunken behaviour:

> London is a complex system out of equilibrium. It's like — it's like a drunken man, blind drunk, in a room with whisky bottles. The whisky is hidden — so he's always walking about looking for it. When he finds a bottle, he takes a long drink, but puts it down and forgets it at once. Then he wonders and looks again, over and over. (p. 202)

At this stage the city — as a complex system — has not yet reached the state of maximal entropy, or chaos, but is still functioning quite predictably. After this, however, '[the man] instantly runs headlong out of the room and into outer darkness. And anything may happen then, anything at all, for the outer darkness is Chaos' (p. 203), thus emphasizing the unpredictability of chaotic behaviour. Such analogies also make the link between nature and humankind stronger by attributing certain distinctively human qualities to chaotic processes: a maximally entropic system implies the creation of a moral vacuum in which anarchy reigns supreme, as is suggested by Mallory's observation of how the inhabitants of London, the 'puppets of base impulse' (p. 220), 'had no proper standards left for judgment or comparison' (pp. 219–20).

Shortly after Mallory has made these observations, he witnesses how the previous chaos gives way to order. Amidst the general anarchy, women and children gather at the Palace of Palaeontology to clean and protect the building, thus reducing the amount of disorder in the city. For Mallory, a firm believer in the values of the British Empire, this event indicates that 'the lurching madness had reached its limit. Within the faltering maelstrom, a nucleus of spontaneous order had arisen! Now, like a cloudy muck resolving into crystals, everything would change' (p. 233). Here Gibson and Sterling again use a simile in order to underline the analogy between natural and social phenomena, foregrounding the idea that the two are part of a continuum rather than separate things. In terms of the popularized accounts of chaos and complexity discussed in 3.2.1, it is noteworthy that Mallory regards the inhabitants' activity as an example of not just any kind of organization but specifically of a spontaneous one. This suggests that in the novel chaos functions in the manner of Ilya Prigogine and Isabelle Stengers's dissipative structures and Stuart Kauffman's autocatalytic processes, both of which possess the capacity to produce order out of chaos on their own. In this sense, rather than being separate from each other, chaos and order co-exist as each other's partners, as is also evident, for instance, in Laurence Oliphant's thoughts about England's current situation. 'The physical and more crudely social cataclysm was past now, certainly,' he notes,

> but Byron's death had triggered successive waves of instability; Oliphant imagined them spreading out like ripples in a pond, overlapping with others that spread from more obscure points of impact, creating ominously unpredictable areas of turbulence. (p. 294)

Foregrounding constant, unpredictable change, this image built on yet another simile indicating the analogy between nature and society suggests that organized systems always already contain the seeds of chaos and vice versa. For this reason, like the umbrella terms of Davies and Kauffman (*chaos* and *the edge of chaos*, respectively) and the antimetaboles of Prigogine and Stengers that reconcile being with becoming in order to communicate the authors' claim that future is never given, it presents the idea that unpredictability sets certain limits for human control.

This interpretation is also suggested by the terms in which Gibson and Sterling approach the question of biological evolution. Reminiscent of Stephen Jay Gould's theory of punctured equilibrium (which I discuss in more detail in 4.3.1), Mallory's theory of evolution, catastrophism, foregrounds the role of the contingent and the accidental in the evolution of the species. He observes how 'the leaping machineries of Evolution were loosed in chaos […] to repopulate the stricken earth with strange new orders of being' (p. 215) after the catastrophe leading to the extinction of dinosaurs. It is Mallory's predominant focus on the sudden appearance of such orders that sets him apart from rival theorists of the age, as is evident in his comments on the evolutionary fitness of dinosaurs:

> The Uniformitarian faction wish these creatures to seem dull and sluggish! Dinosaurs will then fit their slope of gradual development, a slow progression to the present day. Whereas, if you grant the role of Catastrophe, you admit a far greater state of Darwinian fitness for these magnificent creatures […]. (p. 115)

Modelling the rivalry between the Uniformitarians and the Catastrophists after the twentieth-century battle between the gradualism of evolutionary biologists such as Richard Dawkins and the modern catastrophism of Gould and Niles Eldredge, Gibson and Sterling liken biological evolution to processes in chaotic natural systems. In this way, they propose that the sudden transformations in systems at the edge of chaos are similar to the leaps that evolution in the catastrophist view makes from time to time. Indeed, as he observes the chaotic London, Mallory suggestively links the strangely coloured sky above the city to the sky seen by dinosaurs at the moment of their demise, drawing a parallel between biological evolution and complex systems. This comparison recalls Kauffman's juxtaposition of nature and culture through reconciliatory terms pointing to the notion of evolution as a series of crises, with chaos and disintegration always preceding the formation of a new type of order. In other words, rather than signalling an evolutionary or a thermodynamic apocalypse, catastrophe in the novel is an agent of novelty.

A particular example that reflects the difficult-to-predict nature of catastrophic evolution is the portrayal of Mallory's death. After noting that Mallory towards the end of his career had accomplished 'immortal fame' (p. 288) as scientist, the narrator describes how he sits in front of his office desk on the night of his death. The event is framed in terms of making a choice between two alternatives, which is suggested by the fact that there are two piles of documents on Mallory's desk that need to be read. 'One folder lies to his right,' the narrator observes, 'the other to his left, and it cannot be known which he will choose' (p. 289). Having stated this, the narrator proceeds to explain the consequence of the first choice: Mallory chooses the folder on the left, receiving unwelcome news and dying of a failed artery (p. 289). Fortunately for Mallory, however, the 'chain of events' initiated by this choice 'does not occur' (p. 289) because instead of choosing from the left, Mallory chooses the folder to his right and comes across an interesting field report of a palaeontological expedition to the British Columbia, which contains a description of strange fossils that 'bear no relation to any known creature' (p. 290).[20] This gives the elderly scientist conclusive proof of the validity of his catastrophe theory, and he dies in a kind of mystical ecstasy. On the whole, the description of Mallory's death thus foregrounds

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[20] This functions as an allusion to Gould's *Wonderful Life*, which describes the extinction of Cambrian marine life forms in Burgess Shale — an evolutionary catastrophe, in other words.

the fundamentally decisive role of the contingent and the accidental in history — be it either individual or collective — and the difficulty of predicting the future.

Like Gould's vision of evolution as an essentially non-progressive phenomenon, *The Difference Engine* does not imply that evolution should necessarily be associated with improvement. Because the ultimate driving force of evolution in Mallory's catastrophism is chance, it becomes impossible to predict whether the new type of order constitutes an improvement in regard to the old one. 'History works by catastrophe!', Mallory exclaims, 'It's the way of the world, the only way there is, has been, or ever will be. There is no history — there is only contingency!' (pp. 271–72). While society may increase the level of its technological sophistication, such progress does not automatically guarantee that there will be advancement in areas such as ethics or human rights. The difference engines used by the novel's Victorians may help them improve their quality of life in certain areas, but at the same time the steam-driven computer is employed to maintain social inequality instead of erasing it. For instance, the aim of Laurence Oliphant is to use the difference engine as a supreme means of social control:

> Mightn't we examine society, sir, with a wholly new precision and intensity? Divining, thereby, new principles — from the myriad clusterings of population over time, sir; from the most obscure travels of currency from hand to hand, from the turbulent flows of traffic… Topics we now vaguely call police matters, health matters, public services — but perceived, sir, as by an all-searching, an all-pervasive, a scientific eye! (p. 97)

Just as Mallory uses his scientifically trained eye of a palaeontologist to '[distinguish] form amid apparent chaos' (p. 84), so Oliphant envisions a new — and somewhat Orwellian — instrument of control, a metaphorical eye capable of mathematically describing and predicting very complex social phenomena.

Yet, given the fact that the novel — through the explication of Mallory's theories — compares society to a chaotic system, it is not surprising that it explicitly questions the validity of Oliphant's vision. Although it is implied that the Victorian equivalent of a modern intelligence agency, the Central Statistics Bureau, has been successful in developing sophisticated intelligence techniques — as Oliphant enters the Bureau's main building, he notes 'a sense of being observed, somehow — of being known and numbered' (p. 310) — it is also suggested that complete control of neither nature nor society is possible. In France Oliphant is told about a French difference engine called Grand Napoleon, which is presumably based on similar technology as the engines used by the British. He is informed that although the French computer usually works well, its 'higher functions' are plagued by 'an outré element of inconsistency' (p. 347) that points to an element of unpredictability in the system. Indeed, the final section of *Difference Engine* underlines the idea that the Laplacean dream of totally accurate scientific knowledge cannot ever become reality. 'The execution of the so-called Modus Programme demonstrated', Ada Byron notes, 'that any formal system must be both *incomplete* and *unable to establish its own consistency*. There is no finite mathematical way to express the property of "truth"' (p. 376; emphases original). That is, the case of the Modus Programme exemplifies the implications of Gödel's incompleteness theorems in practice, suggesting that totality of the universe is not reducible to a mathematical summary.

At the same time *The Difference Engine* plays with the idea that self-referentiality, on which the functioning of the Modus Programme is based, may be some day utilized to create self-conscious computers that resemble living systems, thus envisioning a co-evolution of humankind and machines, with the latter eventually substituting the former.

The portrayal of this possibility at end of the novel features distinctively dystopian overtones, as the Eye finally reaches the level of self-consciousness in the London of 1991:

> Paper-thin faces billow like sails, twisting, yawning, tumbling through the empty streets, human faces that are borrowed masks, and lenses for a peering Eye. And when a given face has served its purpose, it crumbles, frail as ash, bursting into a dry foam of data, its constituent bits and motes. (p. 382)

From its humble beginning as a vague idea in the minds of Victorians, the Eye has evolved into a self-aware, god-like entity whose consciousness appears to encompass everything. It has become so powerful that it has in its mind created a virtual copy of London through which it maintains and increases its self-awareness. With humankind reduced to electronic information in the mind of a supreme artificial intelligence, the end of the novel exemplifies the primary principles of chaotic self-organization and Mallory's catastrophic theory of evolution. By creating order through autocatalysis and self-referential iteration, life evolves through spontaneous, disjunctive leaps towards an unpredictable future that does not necessarily have anything to do with the present form of humankind, possibly even eventually blurring the border between organic and non-organic modes of existence.

In terms of the challenge that technological progress poses to the current form of humankind, then, *The Difference Engine* displays the same kind of anxiety as many other contemporary stories — *The Terminator* (1984), The Matrix Series,[21] and so forth — that focus on the relationship between humans and machines. If it is accepted that the laws of evolution apply to both biological and technological evolution and that those laws are ultimately ruled by contingency, it becomes very difficult to predict how closely

[21] The series consists of the films *Matrix* (1999), *The Matrix Reloaded* (2003), and *The Matrix Revolutions* (2003).

humankind will merge with its machines. Such view, of course, clashes strongly with the more anthropocentric versions of evolution, suggesting that in a fundamentally indeterministic universe, consciousness and intelligence may not be characteristic properties of only organic beings. (The idea of artificial intelligence as the next protagonist of the evolutionary saga is explored in depth in chapter 5.)

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The question about the relationship between determinism and indeterminism also emerges in Robert Littell's *The Visiting Professor*, which examines these issues in conjunction with the problem of free will. The protagonist of Littell's novel is a Russian 'randomnist' named Lemuel Falk, who arrives to New York to do research in chaos theory at the Institute for Advanced Interdisciplinary Chaos-Related Studies. Lemuel is especially interested in the workings of entropy, 'the relentless slide of the universe towards disorder; towards chaos',[22] and his main aim is to locate 'pure, unadulterated randomness' and separate it from 'fool's randomness' (p. 9), which for him means randomness that is not pure — in other words, chaos. While working on the problem of true randomness, Lemuel gets involved in a serial murder case, which he eventually solves by using his knowledge of randomness: he shows that the murders follow a distinct pattern that underlies the seemingly chaotic appearance of the case. The notion of order emerging out of chaos is also foregrounded through an analogy that Littell draws between nature and human life: in

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[22] Robert Littell, *The Visiting Professor* (London: Faber and Faber, 1993; 1995), p. 5. Further references to this book are given in parenthesis.

addition to the portrayal of scientific research, *The Visiting Professor* features as its subplot a humorous and chaotic love story in which Lemuel meets Occasional Rain, a hippie-like hairdresser who introduces him to the peculiarities of American culture.

Lemuel's research into complex phenomena constitutes an attempt to go beyond chaos, which for him, as noted above, does not equal pure randomness. 'Is it not within the realm of possibility', he asks, 'that the real terminus, the theoretical horizon beyond which there is no other horizon, is pure, unadulterated, non-chaotic randomness?' (p. 55), thus regarding chaos as 'a footprint' (p. 56), or a concrete piece of evidence, of pure randomness. In fact, for him 'chaos is the opposite of [true] randomness' (p. 181) because while chaos always contains a seed of order, pure randomness is characterized by 'perfectly natural absence of order' (p. 182).

It is this search that forms the basis of the novel's exploration of the relationship between indeterminism (free will) and determinism (fate). In Lemuel's opinion, finding evidence of pure randomness would prove that the universe is in some sense truly indeterministic, as its inhabitants would then be capable of making choices according to their free will (p. 57). 'It is because God is alive', he muses, 'because He is randomness incarnate, that all things *are* permitted. […]. Goddamn it, if He can be when and where He will be, then, since we are made in God's image, we can too' (p. 182; emphasis original). In contrast, chaotic systems, in which order underlies apparent chaos, are for Lemuel examples of 'deterministic chaos' (p. 55), whose dynamics derive from their initial conditions without randomness.

The novel explores this relationship mainly through its characters, setting Lemuel's views against those of his roommate, an eccentric rabbi called Rebbe Asher ben Nachman, who at their first meeting introduces himself as ‘the gnostic chaoticist’ (p. 16). For the Rebbe, Yahweh represents ‘the incarnation of randomness’ (p. 21) because the actions of the deity are apparently restricted by neither time nor space. The Rebbe thinks that Yahweh’s random nature is evident especially in his way of punishing people, as the victims can never be certain when and why Yahweh decides to punish them — that is, the effectiveness of Yahweh’s punishments lies in their unpredictability. This unpredictability, however, does not for him imply that the world is indeterministic: he states that ‘everything under the sun is determined even though it’s beyond our power to predict what will come next’ (p. 212) — note the similarity between this view and the one presented in Kate Wilhelm’s *Death Qualified*. For the Rebbe, the world is a chaotic system that behaves according to deterministic laws, and the choices people make have been determined beforehand. It is only our inability to make totally accurate predictions, our inability to know Yahweh, that prevents us from correctly predicting the future. Hence, while the Rebbe sees determinism indicating the existence of a supreme being, for Lemuel it is only the idea of pure randomness that can be associated with such an entity.

This clash of positions is reflected in a subplot in which Lemuel assists the police in solving a case that involves several murders that at first appear to be unconnected to each other. It soon becomes evident that the police have made the mistake of assuming that because there are no significant links between the individual murder cases, the murderer must have chosen the victims at random. However, through his studies of chaotic and complex phenomena, Lemuel eventually discovers that the apparent randomness in the case is truly nothing but apparent, as he realizes that the murderer tries to avoid getting caught by simulating randomness in the choice of his victims. While Lemuel’s computer programme for studying randomness fails to find a strange attractor that would indicate a pattern behind the murders, the very fact that the program comes across only disorder indicates that there has to be a designer who has deliberately tried to avoid creating such a pattern (Polvinen, p. 51). In this sense, the murderer is comparable to Yahweh, whose punishments are only apparently random. The inability of the police to catch the murder draws readers' attention to the more general idea that because its lack of knowledge, humankind is unable to fully grasp the organized complexity of the world, seeing only randomness where there is in fact order.

In contrast to the notion of chaos as deterministic design, the novel presents the idea that pure randomness, which is an essentially indeterministic phenomenon, can be encountered only through chance discovery, not purposeful search — 'When you see a three-piece suit, you *discover* the tailor, you don't *invent* him' (p. 248; emphasis original), as the Rebbe instructs Lemuel. The relationship of Lemuel and Occasional Rain can be seen as an event implying the existence of true randomness: instead of revealing an underlying design, the relationship begins from a chance encounter, as Lemuel goes looking for a haircut on his arrival in the United States. This interpretation is alluded to in the Rebbe's explanation of the correct translation of Yahweh's name: 'Yahweh should maybe be translated, "I will be that I will be". I am personally reading this to mean, "I will be when and where I will be"' (p. 21). Significantly, these are almost the same words that Rain uses to describe herself: '"I am what I goddamn am"' (p. 62), suggesting that symbolically Lemuel's chance meeting of Rain represents a meeting with Yahweh, the embodiment of pure randomness and the designer and creator of chaos. Moreover, it is Rain's name that points to her role as a representative of pure randomness: for Lemuel the fundamental characteristic of pure randomness is ‘the faintest trace of *occasional order*’ (p. 184; emphasis original), the italicized phrase alluding to Rain’s whole name. Therefore, just as the Rebbe finds the ‘the incarnation of randomness’ (p. 21) in Yahweh, Lemuel discovers — or at least approaches — true randomness in the form of his chance encounter with Occasional Rain.

Another example of the idea that it is possible to discover true randomness in occasional rather than designed order is the protagonist’s exploration of mathematics. Lemuel gives a lecture on chaos theory at the local university and illustrates the concept of pure randomness by discussing the role of pi as a transcendental number stretching to infinity. ‘I can say you’, he notes, ‘infinity is something like the horizon seen from a ship — no matter how much you advance toward it, it is always beyond your reach. Trying to calculate pi […] is a going without a getting there’ (p. 174). Lemuel’s comparison suggests that the values of pi expand infinitely without any discernible pattern — save for ‘occasional flashes of […] random order’ (p. 176) — behind the expansion, thus implying pure randomness. What is more, the phrase *a going without a getting there* is in this context significant because it is repeated almost word for word at the end of the novel, as Lemuel and Rain are married to each other. Lemuel’s observation ‘Marriage, when it works, is also a trip without getting there’ (p. 263) puts forth the idea that both mathematics and love can take humans towards the transcendent, which manifests itself as order underlying seeming chaos.

As in the reconciliatory visions of Prigogine and Stengers and Davies, then, *The Visiting Professor* does not propose that the universe is either deterministic or indeterministic, or that its inhabitants either completely lack free will or possess it. On the contrary, it seems to contain both kinds of elements, and Lemuel and the Rebbe hence represent two different but mutually inclusive views that eventually begin to support each other. Lemuel, for instance, learns to accept the Rebbe's view of 'Yahweh-made randomness' (p. 193), while the Rebbe realizes that chaos could be seen as 'a way-station' (p. 211) on the road towards pure randomness. Indeed, in his speech on Genesis at the wedding ceremony, the Rebbe affirms the status of chaos as Yahweh's creation, thus suggesting that order and disorder, determinism and indeterminism, and chaos and pure randomness are always inextricably linked to each other. The marriage of the novel's protagonist can thus be understood as a symbolic reconciliation with the world: instead of being 'on the lam from terrestrial chaos' (p. 274), he learns to embrace its unpredictability and creative potential.

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Let me conclude this subchapter by discussing a story that exemplifies yet another approach to the problem of determinism: Martin Amis's *Time's Arrow*. By focusing on the Holocaust as the key event of the twentieth century, this novel explores the possibility that history is fundamentally a thermodynamic, irreversible process in the sense that it evolves in the deterministic fashion of chaotic systems. In terms of its narration, a marked feature of the story is that its protagonist, who first introduces himself as Tod T. Friendly but whom we later learn to know by his original German name, Odilo Unverdorben, follows as a consciousness separate from his body the various events of his life from the present moment towards the past. This means that instead of simply going through the past in his memories, Tod/Odilo — with his other aliases — witnesses the events unfolding backwards from the time of his death towards his days as one of the camp doctors at Auschwitz, and ultimately, his birth.

The notion of history being an irreversible, thermodynamic process stems from the observation that given the historical circumstances of the 1930s and 1940s, the Holocaust was as unavoidable as the increase of entropy in a closed system.[23] For this reason, Amis's use of reversed narrative can be seen as an ironic device, since it introduces the notion of reversible, Newtonian time only to undermine its validity. Although human consciousness and art may entertain ideas such as time flowing backwards, history itself is impervious to them, which can be deduced from the fact that as a passive witness to history's unstoppable flow, the consciousness occupying Tod/Odilo's body is ultimately incapable of affecting what it sees. Unlike in Ian McEwan's *The Child in Time*, then, there is no possibility of momentarily escaping the flow of time, and Amis's protagonist can merely comment on the unavoidable.

As the backwards narrative unfolds from the present towards the past, it necessarily disrupts causality between things, giving rise to a paradoxical logic. For instance, one of the conceptual oppositions whose causal relationship is affected in this way is the relationship between creation and destruction: in the temporally reverse world of the disembodied narrative consciousness, what are essentially destructive acts become acts of creation. Although Tod has managed to create a successful career in medicine in post-war America,

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[23] Richard Menke, 'Narrative Reversals and the Thermodynamics of History in Martin Amis's *Time's Arrow*', *Modern Fiction Studies*, 44.4 (1998), 959–80 (p. 973). Further references to this article are given in parenthesis.

he is nevertheless subject to recurrent nightmares. 'Around midnight, sometimes', the narrator notes,

> Tod Friendly will create things. […]. Taking hold of the woodwork and the webbing, with a single blow to the floor, with a single impact, he will create a kitchen chair. With one fierce and skillful kick of his aching foot he will mend a deep concavity in the refrigerator's flank.[24]

Through passages such as this, Amis's novel foregrounds the essentially absurd nature of Tod/Odilo's time-reversible world: what to an observer in the world of irreversible time appears as an act of destruction is in the world of the narrative an act of creation.

As the story progresses towards Tod/Odilo's early days as a doctor in America, this logic of reversibility becomes the basis of his medical *modus operandi*, reversing the causality between the primary task of the doctor, healing, and its opposite, causing pain. Consequently, when Tod heals the result is pain:

> You want to know what I do? All right. Some guy comes in with a bandage around his head. We don't mess about. We'll soon have that off. He's got a hole in his head. So what do we do? We stick a nail in it. Get the nail — a good rusty one — from the trash or whatever. And lead him out to the Waiting Room where he's allowed to linger and holler for while before we ferry him back to the night. (p. 76)

Descriptions with a reversed sequence of events such as this one tend to produce the comic effect of watching a film running backwards. As the narrative begins to reveal information about Tod's shameful past, however, the tone of narration becomes darker because reversed causality appears to exonerate the crimes of the German camp personnel. 'It was I, Odilo Unverdorben', the narrator-protagonist announces, 'who personally removed the pellets of

[24] Martin Amis, *Time's Arrow or The Nature of the Offense* (London: Cape; New York: Harmony, 1991), p. 54. Further references to this book are given in parenthesis.

Zyklon B and entrusted them to the pharmacist in his white coat' (p. 121). In the same way, Odilo notes that

> the guards have a habit of touching the women. Sometimes — certainly — to bestow a jewel, a ring, a small valuable. […]. Oh, I think they mean well enough. […]. And they only do it with the angry ones. And it definitely has the effect of calming them down. (p. 121)

Understood in the context of the reversed narrative, the 'Arbeit Macht Frei' slogan is purged of its ironic connotations: those assigned to work — no matter whether they die of it or not — are on a 'path to recovery' (p. 122), as they eventually leave the camp alive and claim their freedom. The officers responsible for separating those fit to work from those sent to the gas chamber become 'matchmakers' (p. 123), who unite families and lovers. As the final result of this humane process, the Jews are 'channeled back into society' (p. 140), and Germany is made a healthy, whole nation again.

Only when viewed backwards from the perspective of Tod/Odilo's disembodied consciousness, then, the events leading to the Holocaust appear to make sense. Indeed, it is at the beginning of the fifth chapter that the 'world is going to start making sense' (p. 116) for the novel's protagonist. It is now Odilo who takes the role of the narrator, as his earlier, split consciousness is unified ('Was there a secret passenger on the backseat of the bike, or in some imaginary sidecar? No. I was one' (p. 116)). In Auschwitz he gradually grows more powerful and begins his work of healing and creation. Odilo's observations are still characterized by the absurd logic that emerges from viewing everything backwards. 'The hearty trek and the bracing temperatures', he notes of inmates returning from the death march following the evacuation of the camp, 'had obviously done the men good, though their condition, on arrival, left much to be desired' (p. 118). In the same way, destructive acts are still acts of creation, as Odilo remarks of the 'preternatural purpose' of National Socialism: the Nazis seek to 'dream a race. To make a people from the weather. From thunder and from lightning. With gas, with electricity, with shit, with fire' (p. 120).

The idea that the Holocaust makes sense only in reverse is further foregrounded by the fact that Odilo's world stops 'making sense again' (p. 147) at the beginning of the sixth chapter, where the novel's narrative duties are once again taken over by the observing consciousness, allowing Amis to comment on the moral qualities of his protagonist. Although the Holocaust may seem a senseless phenomenon when studied from the beginning to the end, there is nothing in the pre-Auschwitz Odilo that could not be rationally explained. Instead of an Aryan superman, he is in the narrator's eyes 'absolutely unexceptional, liable to do what everybody else does, good or bad, with no limit, once under the cover of numbers' (p. 157). With its absurd logic, the backwards narrative is reminiscent of Prigogine and Stengers's incrementum that illustrates the notion of reversible-time universe as an abstraction far removed from physical reality.

The fact that the backwards narrative ultimately leads to the identification of the protagonist's moral qualities strongly suggests that his identity is a product of time, of history. The idea that time is the formative element of human identity is evident in the novel's observation that humans are able to imagine histories built on logic that somehow contradicts their commonsense view of temporal progression through art. The narrator describes how Tod/Odilo visits the Metropolitan Museum of Art, and becomes aware of the idea of reversible time through the paintings exhibited there. 'Like writing,' the consciousness observes the protagonist's reactions, 'paintings seem to hint at a topsy-turvy world in which, so to speak, time's arrow moves the other way. The invisible speedlines suggest a different nexus of sequence and process' (p. 87). In contrast, in the physical world time's arrow is bound to point to one direction only: the future. Although for Tod/Odilo the world makes more and more sense as the story progresses towards his past, it is obvious that for readers living in the world of irreversible time, the reversed narrative portrays a world devoid of common sense. In this respect, as Richard Menke correctly observes, *Time's Arrow* 'emphasizes the connection between time and consciousness' (p. 972), making irreversible time a basic element of the individual self — indeed, the narrator acknowledges the existence of this link by noting that 'time [...] makes us everything we are' (p. 68). Hence, like Prigogine and Stengers for whom irreversibility unites the physical (the world) and the mental (consciousness), Amis grants time a role that is fundamental for the constitution of human identity. (Note how this also echoes Prigogine's use of Borges's antimetaboles as a means of efficiently establishing a link between irreversible processes and the constitution of the self.)

However, unlike Prigogine and Stengers, who celebrate the role played by indeterminism, Amis draws attention to the idea that as the defining features of human life, time subjects the individual to a certain kind of historical determinism. 'What goes around comes around', the narrative consciousness notes, '1066, 1789, 1945' (p. 9). This suggests that the novel views history as a more or less predictable phenomenon in which certain kinds of events take place repeatedly. Since history is bound to repeat itself in a cyclical fashion, the individual appears to be powerless before it: for instance, the narrator remarks how time 'pours past unpreventably, like the reflection on a windshield as the car speeds through city or forest' (p. 58), as it does for the protagonist. Indeed, like the events leading to the Holocaust itself, Odilo's actions are more or less predictable if seen against the background of the historical situation in which he is situated. This leads the narrator to conclude that ‘he could never be an exception; he is dependent on the health of his society’ (p. 157). Therefore, even though time’s arrow reverses its direction in the novel, the reversal merely serves to underline the fact that there is no escape from the deterministic one-way time of history (Menke, p. 973).

It is in this respect, then, that the biggest difference between Prigogine and Stengers’s philosophy of irreversibility and the view of time in Amis’s novel emerges. While both accounts argue for an inseparable link between time, the world, and the individual, the former seek to reconcile determinism and indeterminism, arguing that given the stochastic nature of chaotic processes, the future is not necessarily determined by the past. The latter, as the above examples show, suggests that history is a more or less deterministic phenomenon. The reversed narrative of *Time’s Arrow* cannot but point only to the past, confirming the narrator’s statement ‘The future always comes true’ (p. 155). As in Prigogine and Stengers’s representation of chaos, chaotic events do eventually become organized in *Time’s Arrow*, but the novel undermines this through the sense of absurd evoked by the reversed narrative.

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The above analyses show that contemporary fiction uses ideas from chaos theory and complexity in order to approach issues related to knowledge — holism, unpredictability, and the relationship between determinism and indeterminism. As in the case of literary works responding to the ideas of the new physics, this is accomplished by drawing an analogy between nature and human life, the former functioning as a model that structures the portrayal of the latter. For instance, in Connie Willis's *Bellwether* and Robert Littell's *Visiting Professor*, plots progress from chaos to unification, as characters are eventually united in the manner characteristic of comedy. In addition, Willis links her portrayal of human relationships to the portrayal of the relationship between the individual and the world through imagery suggesting a distinctively holistic outlook. Similarly, Kate Wilhelm's *Death Qualified* stresses the importance of adopting a holistic view by its structure and images: chaos is presented as a state that precedes the emergence of a new level of understanding in the protagonist's consciousness.

The unpredictability associated with chaotic systems is made a part of human life in Michael Crichton's *Jurassic Park* and William Gibson and Bruce Sterling's *The Difference Engine*. Foregrounding holism in the manner of Willis and Wilhelm, Crichton focuses on the idea that nature's complexity effectively resists human control by the explication of chaos theory and the structure of his novel. The notion of vast-scale complexity undermining the possibility of control is in the same way explored by Gibson and Sterling, who compare society and history to chaotic systems through various analogies and suggest that indeterminism is a fundamental feature of temporal processes in both nature and human life. The question about the relationship between determinism and indeterminism also underlies Littell's novel, which through characterization and structure makes them complementary building blocks of the world. Finally, Martin Amis's *Time's Arrow* presents yet another angle from which the problem of determinism can be viewed: Amis uses backwards narrative as a formal element that questions the possibility of changing the course of thermodynamic processes. Although it in this regard differs from the novels emphasizing the unpredictability of history, Amis's novel nevertheless establishes an intimate link between the individual and the world by making both products of irreversible time.

3.3 Chaos as Romanticism and Romance

Having studied how contemporary popular science writing and fiction examine the human relevance of chaos and complexity, I now conclude my discussion by considering an interesting feature that has to some extent contributed to the cultural status of chaos theory: its representation as a distinctively Romantic science. This feature is worth analysing because it is so evident in two well-known texts on the subject: James Gleick's influential popularization *Chaos* and Tom Stoppard's play *Arcadia*. While Gleick tells the story about the history of the science by portraying its seminal personalities as more or less revolutionary Romantic characters, Stoppard makes the link by presenting chaos theory as an intellectual descendant of Romanticism, as it attends to the irregularity and unpredictability of the physical world.

3.3.1 Revolutionary Scientists, Revolutionary Ideas

The story of the history of chaos theory in Gleick's *Chaos*, which is without a doubt the most famous popular science book on the topic, is structured around the portraits of various illustrious personalities behind the science, such as Edward Lorenz, Mitchell Feigenbaum, Benoit Mandelbrot, David Ruelle, and Robert Shaw.[25] The common denominator in the

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[25] Since Daniel Cordle's discussion on the shared discourses of contemporary popular science writing and fiction in *Postmodern Postures* already features a good analysis of some of the crucial rhetorical strategies in

thinking of these scientists is that they see chaos as ‘the hidden order that exists *within* chaotic systems’ (Hayles, *Chaos*, p. 9; emphasis original). For this reason, the kind of chaos that Gleick presents to his readers differs from the concept of true randomness in the sense that chaotic phenomena is seen to give rise to complex yet ordered patterns of behaviour that are known as strange attractors (Hayles, *Chaos*, p. 9). Consequently, as N. Katherine Hayles observes, the main difference between the strange attractor branch and the order-out-of-chaos paradigm of Ilya Prigogine and Isabelle Stengers is that the former focuses on systems that exhibit continuous chaotic behaviour, and is as such mainly interested in ‘the orderly descent into chaos rather than on the organized structures that emerge from chaos’ (*Chaos*, p. 10). In other words, theorists working in the strange-attractor branch are interested in systems that are seemingly disordered but which on a closer inspection reveal deeply structured order.

Gleick begins his story by focusing on one of the most well-known concepts in the history of chaos theory: the butterfly effect. Illustrating the idea through its inventor, he gives an account the life of the meteorologist Edward Lorenz, who is widely regarded as an early pioneer of chaos. Interestingly, Gleick portrays not only Lorenz’s life but also describes his physical characteristics and personality:

> Indeed, if the eighteenth-century philosophers imagined their creator as a benevolent noninterventionist, content to remain behind the scenes, they might have imagined someone like Lorenz. He was an odd sort of meteorologist. He had the worn face of a Yankee farmer, with surprising bright eyes that made him seem to be laughing whether he was or not. He seldom spoke about himself or his work, but he listened. He often lost himself in a

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Chaos — such as Gleick’s characterization of seminal chaos theorists as Romantics and frontiersmen, and the book’s narrative structure — my own analysis attempts to extend it by concentrating on the various figures of speech in Gleick’s portrayal of both the scientists and their ideas.

> realm of calculation or dreaming that his colleagues found inaccessible. His closest friends felt that Lorenz spent a good deal of his time off in a remote outer space. (pp. 12–13)

This passage shows that as in the case of the other similar vignettes in *Chaos*, Gleick's portrayal of the scientist imposes on him characteristics that are often associated with Romantic individuals. For instance, Lorenz's unwillingness — or inability — to communicate his unique ideas to others and his willingness to pursue his scientific goals alone are examples of traits traditionally linked to Romantic geniuses. From the viewpoint of Gleick's rhetoric, we are thus invited to treat the passage as a figure of description that identifies the main characteristics of the subject.[26] In the context of Gleick's history of chaos theory, the description has an important function because it links the characteristics of a certain type of individual to the characteristics of the actual science: for Gleick, chaos is as unique a phenomenon as a science as Lorenz is a unique personality as a scientist. In this sense, then, we could say that Gleick's description of Lorenz's personal traits functions as a metonymy for the Romantic science of chaos theory.

Gleick then goes on to describe how Lorenz's mathematical modelling of weather led him to discover the butterfly effect, noting how Lorenz found out that his models showed 'order *masquerading* as randomness' (p. 22; emphasis original). The meteorologist saw that there was a link between the fact that weather did not repeat itself and the various difficulties in predicting weather — that is, Lorenz determined that there was a link between irregularity and unpredictability (Gleick, p. 22). In the case of chaotic behaviour in nature, the butterfly effect manifests itself as sensitive dependence on initial conditions,

[26] Classical rhetorical theory lists many types of figures of description, such as characterismus (the general description of a person's character), effictio (the description of a person's bodily features), and ethopoeia (the description of a person's habits).

meaning that it is impossible make long-term predictions concerning the development of complex systems because such systems are highly sensitive to change. In order to illustrate how small changes in initial conditions may give rise to large-scale consequences, Gleick quotes a well-known folk rhyme: '*For want of a nail, the shoe was lost; | For want of a shoe, the horse was lost; | For want of a horse, the rider was lost; | For want of a rider, the battle was lost; | For want of a battle, the kingdom was lost!* (quoted in Gleick, p. 23; emphasis original). Although the rhyme does not strictly follow the syntactic form of gradatio, it nevertheless uses an interconnected series to create a sense of causal continuity. As such, it actually exemplifies the use of coenotes, a figure of repetition that like its close relative, symploche, combines the principles of anaphora and epistrophe to repeat both the beginning and end of successive structures. Instead of repeating individual words as its relatives do, however, coenotes repeats phrases at the beginning and end of lines. Progressing gradually from the smallest item towards the biggest one, the series uses repetition to foreground the idea that in the development of complex systems 'a chain of events can have a point of crisis that could magnify small changes' (Gleick, p. 23). On the basis of the above analysis of fiction inspired by chaos theory, we could say that this kind of figural logic underlies the portrayal of chaotic processes in all the stories, as it describes interlinked events giving rise to unpredictable novelty.

Gleick's discussion of another fundamental concept in chaos theory, self-similarity, employs narrative structure similar to the one in the chapter on Lorenz and the butterfly effect. Gleick begins examining the concept by first drawing a portrait of its discoverer, the Polish-born mathematician Benoit Mandelbrot, emphasizing his visionary qualities. 'Unlike most mathematicians', Gleick describes Mandelbrot, 'he confronted problems by depending on his intuition about patterns and shapes. He mistrusted analysis, but he trusted his mental pictures' (p. 84). Moreover, like Lorenz, Mandelbrot is characterized as an isolated figure. 'He was always an outsider', Gleick writes,

> taking an unorthodox approach to an unfashionable corner of mathematics, exploring disciplines in which he was rarely welcomed, hiding his grandest ideas in efforts to get his papers published, surviving mainly on the confidence of his employers. (p. 87)

He thus paints a picture of Mandelbrot as a Romantic visionary, who prefers intuition over intelligence, and social and professional isolation over communal existence.

After having characterized Mandelbrot in such a manner, Gleick proceeds to discuss his main contribution to chaos theory: the idea of self-similarity. Working on fields as different as information theory, economics, and fluid dynamics, Mandelbrot discovered structures in which the whole is more or less similar to its parts. This means that such structures display 'symmetry across scale' (Gleick, p. 103), as the pattern of the whole is repeated at smaller and smaller scales in the patterns of the individual parts. Probably the most well-known example of a self-similar pattern is the fractal, a curve or geometrical figure whose parts have the same statistical character as the whole (famous examples in nature that can be modelled through fractal geometry include coastlines and snowflakes).

As self-similarity in nature is based on the repetition of patterns across various scales, it is perhaps not surprising that the accommodation of the notion into language also makes use of repetition. Gleick notes that when talking about fractals, Mandelbrot had the habit of quoting the following lines from Jonathan Swift in 'On Poetry: A Rhapsody' (1733): 'So, Nat'ralists observe, a Flea | Hath smaller Fleas that on him prey, | And these have smaller Fleas to bite 'em, | And so proceed ad infinitum' (quoted in Gleick, p. 103). The quotation is rhetorically effective in terms of describing the idea of self-similarity because it is built on repetition characteristic of gradatio: the interlinked series of fleas can be thought to extend to infinity at increasingly smaller scales. The same idea is also evident in Gleick's own linguistic formulation describing self-similarity, in which a fractal is likened to 'the cartoon notion of a fish eating a smaller fish eating a smaller fish eating a smaller fish' (p. 103). In rhetorical terms, this is epizeuxis, a figure of uninterrupted repetition, which typically expresses strong emotions. Gleick, however, does not seek to express his awe of fractals but, like Swift, takes advantage of the iconic potential of those figures of speech that incorporate repetition in order to linguistically accommodate the notion of nature being full of seemingly infinite, repetitive patterns.

For Gleick, the claim that self-similarity is indeed a characteristic feature of nature has important implications concerning the way in which humans perceive natural phenomena. For instance, if we take for granted the idea that self-similar patterns extend across different-sized scales, it becomes obvious that we must pay attention not only to individual phenomena but also to the relationships that they form with other types of phenomena:

> *Hurricane*. By definition, it is a storm of a certain size. But the definition is imposed by people on nature. In reality, atmospheric scientists are realizing that tumult in the air forms a continuum, from the gusty swirling of litter on a city street to the vast cyclonic systems visible from space. Categories mislead. The ends of the continuum are of a piece with the middle. (p. 108)

In this passage we can see how the idea of self-similarity points to the importance of a holistic approach to nature. Gleick notes that in evolutionary biology, for instance, it soon became necessary 'to recognize patterns of development in genes, in individual organisms, in species, and in families of species, all at once' (p. 116). Through this incrementum he foregrounds the idea that such an approach focuses on the interaction (as suggested by the phrase *all at once*) of the parts of the whole: although the series ascends towards the largest item, none of the items is privileged over the others, as there are only recurring patterns at different scales across a continuum.

However, it should also be pointed out that although linguistic structures based on repetition may help illustrate how nature's self-similarity is structured, they might lead one to think that the self-similar patterns are based on the sameness of elements. On the contrary, such patterns are a mixture of sameness and difference, as Gleick explains when discussing the work of the French mathematician Adrien Douady and his American colleague John Hubbard on the structure of the so-called floating molecules:

> The mathematicians proved that any segment […] would, when blown up by the computer microscope, reveal new molecules, each resembling the main set and yet not quite the same. Every new molecule would be surrounded by its own spirals and flame-like projections, and those, inevitably, would reveal molecules tinier still, always similar, never identical, fulfilling some mandate of infinite variety, a miracle of miniaturization in which every new detail was sure to be a universe of its own, diverse and entire. (pp. 228–29)

The seemingly antithetical juxtaposition of similarity and difference (*each resembling the main set and yet not quite the same*; *always similar, never identical*; and *diverse and entire*) in the passage also recalls other conceptual pairings that seem to be characteristic of chaos theory. For instance, when talking about the influence of chaos theory on the research of artificial intelligence, Gleick notes that a 'physicist thinking of *ideas* as regions with fuzzy boundaries, separate yet overlapping, pulling like magnets and yet letting go, would naturally turn to the image of a phase space with "basins of attraction"' (p. 299; emphasis original). In the same way, he uses the phrase 'Life sucks order from a sea of disorder' (p. 299) to describe the manner in which living organisms function, and quotes a scientist studying heartbeat sequences as saying that ‘there is often some type regularity in these numbers, but there is often great irregularity also. It’s one of the slogans in this business: order in chaos’ (quoted in Gleick, p. 291).

As discussed in 2.2.1, however, instead of suggesting relationships based on opposition, such juxtapositions indicate complementary relationships of contrary terms and point to the logic underlying figures of speech such as oxymoron and synoeciosis, which both express the union of contraries. Indeed, as many of the slogans associated with chaos theory imply, such pairings make a strong argument about the nature of reality. Instead of encouraging scientists to follow the logic of either/or in their thinking, chaos theory has forced them to think in terms of the logic of both/and — just as the new physics has done. Paradoxically, then, in chaos theory chaos and order are separate yet overlapping phenomena in the same way the self-similarity created by their interaction displays the characteristic pattern of sameness and difference — as I showed in my analysis of Kate Wilhelm’s description of fractal patterns, synoeciosis structures their linguistic representation by juxtaposing seemingly opposite concepts.

Repetitive linguistic patterns, such as the ones discussed above, also have an iconic function in Gleick’s discussion on strange attractors. These equations or fractal sets are used in the representation of systems that characteristically display turbulence, which develops when the flow of a fluid or air turns from smooth and ordered into uneven and chaotic. In order to illustrate the structure of turbulence — circular movement contained within circular movement — Gleick quotes the English mathematician, physicist, and psychologist Lewis Fry Richardson, who humorously captures the essence of the art and science of forecasting weather: ‘*Big whorls have little whorls* | *Which feed on their velocity,*

| *And little whorls have lesser whorls* | *And so on to viscosity*' (quoted in Gleick, p. 119; emphasis original). For Gleick, the gradatio-like pattern of Richardson's lines is obviously an apt representation of the *modus operandi* of turbulence, which, like a fractal, is fundamentally a phenomenon consisting of many interlinked layers. Hence, the series of items linked together through repetition linguistically accommodates the idea that turbulence 'is a mess of disorder at all scales, small eddies within larger ones' (Gleick, p. 122).

Mathematically, this kind of phenomena can be described through strange attractors. Gleick notes that a German medical doctor interested in chemistry and theoretical biology described a strange attractor as 'a sausage in a sausage in a sausage in a sausage' (quoted in Gleick, p. 141). Through its marked use of repetition, the doctor's epizeuxis linguistically represents an important feature found in strange attractors, such as those named after Edward Lorenz, who in 1963 draw the first model of such a shape, and the French astronomer Michel Hénon, whom Gleick credits with producing 'the most illuminating strange attractor' (p. 144). 'Like Lorenz's attractor,' Gleick notes, 'Hénon's displays infinite regress, like an unending sequence of Russian dolls one inside the other' (p. 150). In this way, the epizeuxis offers an iconic way of representing the 'lines within lines' (Gleick, p. 160) characteristic of strange attractors.

Because a strange attractor such as the Lorenz attractor is more or less a symmetrical figure — its two halves are almost mirror images of each other — we could think of it in terms of the figure of speech that, as we saw in chapter 2, is often used to describe relationships based on symmetry and balance: antimetabole. This is evident especially in the pictures of the Lorenz attractor, which for Gleick bears similarity to the highly symmetrical shapes of ‘an owl’s mask or butterfly’s wings’ (p. 29). The sense of symmetrical reciprocity characteristic of antimetabole is reinforced by Gleick’s commentary on the same image, which compares the visual representation of the mathematical equation to a water-wheel in motion:

> Because the system never exactly repeats itself, the trajectory never intersects itself. Instead it loops around and around forever. Motion of the attractor is abstract, but it conveys the flavor of the motion of the real system. For example, the crossover from wing of the attractor to the other corresponds to a reversal in the direction of spin of the waterwheel or convecting fluid. (p. 29)

In terms of the notion of the Lorenz attractor as a visual antimetabole, the key phrases and words in the passage are *loops around and around forever*, *crossover*, and most importantly, *reversal*. In this way, the visual antimetabole shows that the system forms a continuous loop in which motion reverses its direction each time it crosses from one wing to the other.

As stated in the introduction of this chapter, one of the major insights of chaos theory is that chaotic phenomena are a rule rather than exception in nature — a discovery that invalidates the earlier view of disorder and irregularity as marginal features. Gleick approaches the question about the universality of chaos through the portrayal of yet another seminal pioneer of chaos theory: the mathematical physicist Mitchell Feigenbaum, whose main contribution to the emerging field during its early days was the discovery that ‘different [real-world] systems […] behave identically’ (p. 180). The discussion begins with a description of Feigenbaum observing the flow of a stream in a natural setting:

> A few dozen yards upstream from a waterfall, a smooth flowing stream seems to intuit the coming drop. The water begins to speed and shudder. Individual rivulets stand out like coarse, throbbing veins. Mitchell Feigenbaum stands at a streamside. He is sweating

slightly in sports coat and corduroys and puffing on a cigarette. He has been walking with friends, but they have gone ahead to the quieter pools upstream. (p. 157)

Given the fact that Gleick portrays the history of chaos theory as a distinctively revolutionary phenomenon, it may be significant that the passage depicts Feigenbaum having parted with his company to watch the flow of water turn from ordered to turbulent. This act draws attention to the notion of chaos as a science created by similarly revolutionary solitary visionaries, who have chosen to take paths of research ignored by other scientists. In contrast, with their consensus of vision and limited insight, the others are content to study easier questions, as suggested by the phrase *the quieter pools*, which links their research to ordered, non-chaotic natural phenomena.

In addition to this description, there are other features in Gleick's story of chaos that make Feigenbaum a crucial character; as Daniel Cordle observes he is 'the figure who draws all the other stories about chaos together' (p. 82). In fact, Feigenbaum is the character that most clearly embodies the Romantic qualities associated with his science. For instance, in the prologue Gleick describes Feigenbaum's appearance as follows: 'His hair was a ragged mane, sweeping back from his wide brow in the style of the busts of German composers. His eyes were sudden and passionate' (p. 2). Suggestive of the various sculptures of Beethoven, the passage links Feigenbaum to Germany and through Germany, to a seminal Romantic whom Gleick in the same chapter names as a paradigmatic example of the holistic approach: Goethe. (Gleick's characterization of Feigenbaum also foregrounds the observation that the scientist 'tended to drop articles and pronouns in a vaguely middle European way' (p. 2) and that his record collection was 'solidly Germanic'

(p. 184).) Hence, by portraying Feigenbaum in certain settings and through his external appearance, Gleick metonymically links him to the Romantic tradition.

3.3.2 Reconciling Reason and Emotion

The idea that chaos theory is a fundamentally Romantic science with revolutionary ideas conjured up by equally revolutionary individual practitioners is also found in contemporary drama. An evident example of this is Tom Stoppard's *Arcadia*, which, like *Hapgood*, approaches questions related to human identity and knowledge through the theories of the natural sciences.[27] More specifically, like Kate Wilhelm's *Death Qualified*, Stoppard's play uses chaos theory as a means of constructing an intellectual framework for studying the relationship between human perception and the world. This relationship is present in two fundamental insights that the play's characters encounter: firstly, they realize that like that of nature, the complexity of life always exceeds the human ability to perceive and understand it in full; secondly, in spite of this, they are made aware of the idea that the chaos of human life is not devoid of purpose although it may appear to be so (Polvinen, p. 53). Stoppard thus does not suggest that the fundamentally chaotic nature of the world prevents access to accurate knowledge: although chaotic behaviour is a result of a vast

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[27] Stoppard acknowledges his intellectual debt to Gleick's popularization in an interview in which he states that he 'got tremendously interested in a book called *Chaos* by James Gleick which is about this new kind mathematics'. Tom Stoppard, 'In a Country Garden (If It Is a Garden)', in *Tom Stoppard in Conversation*, ed. by Paul Delaney (Ann Arbor: University of Michigan Press, 1994), pp. 261–64 (p. 263).

number of interconnected factors, we do not need to be aware of all of them in order to arrive at such knowledge (Polvinen, p. 53). In other words, the play emphasizes the necessity of adopting a holistic viewpoint through which to approach the seemingly chaotic complexity of life.

The action of *Arcadia* takes place in a single room in Sidley Park, a country house owned by the aristocratic Coverlys during two periods, 1809–12 and the present day. While the former period follows the education of the thirteen-year-old Thomasina Coverley by her tutor, Septimus Hodge, the latter period focuses on the attempts of the author Hannah Jarvis and the literary scholar Bernard Nightingale to discover answers to questions concerning a famous visitor in Sidley Park's past, Lord Byron. At the same time, Valentine Coverly, heir to Sidley Park, discovers Thomasina's notebooks on mathematics and realizes that the work of their young author should be considered a rough precursor of modern studies in complex natural phenomena. Hence, through these events the plot of the play creates a continuum between the past and the present of the country house.

In terms of the play's portrayal of chaos theory, it is significant that Stoppard has chosen to juxtapose the middle of the Romantic period with the present day, hence suggesting a close link between Romanticism and ideas in modern natural sciences (Valentine is engaged in biological research by using mathematical models of complex behaviour). More specifically, Stoppard portrays the former period as a transitional period during which the ideas of the Enlightenment gave way to those of Romanticism and in this way explores the relationship between two different types of knowledge, as the rational worldview of the former creates a contrast to the emphasis given to inspiration and irrationality in the latter.

In the context of the scientific ideas used in the play, this contrast is manifest especially in the question about the status of order and disorder as the two complementary organizing principles of reality. More specifically, Stoppard approaches their relationship by depicting Thomasina's education. Growing up in the early 1800s, she is taught to think in terms of the worldview of the Enlightenment, in which the world functions as a gigantic, predictable clockwork mechanism. However, during Septimus's lessons in mathematics, Thomasina's perceptive and critical mind makes her wonder whether 'God is a Newtonian'[28] or not. Alluding to the idea of God as the supreme mathematician, she summarizes the implications of Newtonian physics for predicting the future as follows:

> 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. (p. 13; emphasis original)

From the viewpoint of the Newtonian worldview, then, it is theoretically possible to accurately predict future, because 'everything from the furthest planet to the smallest atom of our brain acts according to Newton's law of motion' (p. 13) in a strictly deterministic fashion. From this follows that in such a universe, temporal processes are in theory completely reversible because they always follow the same universal laws.

Thomasina, however, has observed that in real life, temporal processes cannot be reversed in the manner of Newtonian mechanics. For instance, she notices that it is impossible to reverse the process of mixing jam into rice pudding: 'if you stir backward, the jam will not come together again. Indeed, the pudding does not notice and continues to turn

[28] Tom Stoppard, *Arcadia*, in *Tom Stoppard: Plays Five* (London: Faber and Faber, 1993; 1999), pp. 1–137 (p. 13). Further references to this play are given in parenthesis.

pink just as before' (p. 12). On the basis of her everyday observations, she begins to see the limitations of the Newtonian worldview, especially regarding the fact that Newton's equations are incapable of accommodating the complexity of nature. She complains to Septimus that the equations she studies under his tutelage give rise to forms that are 'nothing but arcs and angles', which allow the divine watchmaker the limited choice of 'only mak[ing] a cabinet' (p. 55). Frustrated by the limitations of such mathematics, Thomasina turns to the world of complex natural shapes by deciding to write an equation for an apple leaf.

By turning her focus from the predictable and regular — the preferred shapes of the Enlightenment thought — to the random and irregular, Thomasina becomes an early pioneer of chaos theory. The fact that there is continuity between her vision and the thought of twentieth-century explorers of natural complexity is shown by the portrayal of Valentine as continuing Thomasina's work: the latter's studies on iterated algorithms, which she plans to use in order to calculate the equation for the apple leaf, are based on the same ideas as his mathematics of grouse populations. At the level of the play's symbolism, this is represented by Hannah's act of picking up an apple leaf, as she listens to Valentine's explanation on iterated algorithms. Hence, both the leaf and grouse populations are examples of 'the mathematics of the natural world' (p. 65), which attempts to capture the essential complexity of nature.

The link between Thomasina's interest in irregularity and Romanticism is also evident in the way the play contrasts the geometry of shapes such as that of the apple leaf to the regularity of early nineteenth-century gardens. The surroundings of Sidley Park are being redesigned by Mr Noakes, a landscape architect, who plans to change their appearance from symmetrical to the newly fashionable irregular. In Hannah's retrospective view, the change taking place in the surroundings of Sidley Park becomes a symbol of the paradigm shift from the Enlightenment to Romanticism. Indeed, at the beginning of the second act, we learn of her hypothesis that after Thomasina's death, Septimus went to live in a hermitage built in the park's premises. This too symbolically represents the shift in the relationship between the two types of knowledge, 'The Age of Enlightenment banished into the Romantic wilderness' (p. 94), as Hannah puts it. For her, however, the change is on the whole a negative one because it signals the 'decline from thinking to feeling', as the focus of the new paradigm turns from reason and order to what she sees as 'cheap thrills and false emotion' (p. 43). This, as William W. Demastes observes, shows that the Newtonian mindset is still very much alive in the play's modern setting, although characters such as Hannah are eventually forced to face its limitations when confronted with the world's complexity (p. 99).

However, in the context of the play's juxtaposition of order and chaos, the Enlightenment and Romanticism, Hannah's views function only to highlight her own inability to cope with emotions, especially when they concern the opposite sex. 'Chaps sometimes wanted to marry me,' she notes, 'and I don't know a worse bargain. Available sex against not being allowed to fart in bed' (p. 90). Moreover, in the fifth scene of the second act, we learn that she does not believe in Bernard's theory that Byron would have actually fought a duel because of his passion for Mrs Chater, the wife of the poet and amateur biologist Ezra Chater, who is one of the guests staying at Sidley Park at the time of Byron's visit. Hannah also disapproves of Chloë Coverly's budding sexuality and remains indifferent to the interest that Gus Coverly and Valentine show in her. Because of her defensive attitude towards the emotional side of human life, she prefers to see the Enlightenment version of Sidley Park as a 'paradise in the age of reason' simply because all emotion has been banished from it through exclusive reliance on 'intellectual rigor' (p. 43). In this sense, then, Hannah's character embodies the notion of reason and emotion as opposite concepts.

Through the exposition of ideas related to chaos theory, however, the play suggests that ideally, reason and emotion should be balanced with each other. This is alluded to in Valentine's description of order and disorder as the two complementary forces that create the geometry of the natural world: 'The unpredictable and the predetermined unfold together to make everything the way it is. It's how nature creates itself, on every scale, the snowflake and the snowstorm' (p. 68). Indeed, the last scene of the play indicates that even the emotionally detached Hannah needs to complement her rationality with emotion: after receiving Thomasina's original folio as a gift from Gus, which confirms her thesis that Septimus was the hermit of Sidley Park, she accepts her admirer's invitation to dance. Similarly, the dance of Septimus and Thomasina, which structurally parallels that of Gus and Hannah, can be understood as an eventual reconciliation between the values of the Enlightenment and Romanticism, blending order and disorder, and intellect and emotion, in the deterministic chaos of chaos theory. Reminiscent of Gleick's idea that chaos has made scientists regard the world in terms of complementary qualities — which Gleick expresses through synoeciosis — these examples imply that like *Hapgood*, *Arcadia* seeks to show how a new kind of worldview needs to acknowledge the coexistence of seemingly opposite qualities.

Closely linked to such considerations is the question about the science's relevance to our understanding of time and, consequently, the role of chaos in shaping a worldview that is meaningful from the viewpoint of humankind. For instance, Thomasina's observation about stirring jam in a pudding suggests that the concept of free will is inextricably linked to our understanding temporal processes. Her discovery indicates that temporal processes cannot be reversed ('if you stir backward, the jam will not come together again' (p. 12)), but Septimus fails to grasp the implications of this for the time-reversible worldview of Newton in his answer:

> Time must needs run backward, and since it will not, we must stir our way onward mixing as we go, disorder out of disorder into disorder until pink is complete, unchanging and unchangeable, and we are done with it for ever. This is known as free will or self-determination. (p. 12)

Septimus's answer is clearly self-contradictory, because he insists that we must create disorder even though he at the same time links this to the notion of free will granting individuals the possibility of making choices. In fact, the Newtonian universe, in which the future can accurately be predicted from our past and present observations, effectively denies the possibility of free will, as Septimus himself notes: 'If everything from the furthest planet to the smallest atom of our brain acts according to Newton's law of motion, what becomes of free will?' (p. 13). His answer, 'God's will' (p. 13), expresses the idea that individuals, as cogs in the machinery of a universe devised by the celestial watchmaker, cannot affect the course of their fates, just as planets and atoms cannot change their individual, entirely predictable trajectories.

In the seventh scene of the second act, we find Chloë and Valentine pondering on the same problem. Summarizing the worldview of the Newtonian universe, Chloë notes that in terms of free will, the idea that 'the future is all programmed like a computer' implies that individuals are ultimately 'just a lot of atoms bouncing off each other like billiard balls' (p. 103). Although Valentine explains to her that the idea of a completely deterministic universe has been shattered by recent developments in mathematics, Chloë comes up with an alternative explanation for why it is impossible to predict the future completely accurately: 'The universe is deterministic all right, just like Newton said, I mean it's trying to be, but the only thing going wrong is people fancying people who aren't supposed to be in that part of the plan' (p. 104). Indeed, on the basis of what kinds of relationships are formed in the play, Chloë's argument appears to capture at least one major source of unpredictability at the macroscopic level of everyday life: desire. For instance, while Septimus is sexually fascinated by Mrs Chater but does not feel genuine affection towards her, he enjoys a similar relationship to his employer, Lady Croom, who is obviously much older than him. Thomasina in turn becomes attached to Septimus, but the latter cannot let the affair progress beyond kissing because of his status as her tutor. Moreover, Chloë has sex with the much older Bernard, who views her only as a sexual conquest. As noted above, the feelings of Valentine and Gus for Hannah have little chance of getting response from their object because of Hannah's cynical view of men and emotions. Although the end of the play suggests that she might have feelings for Gus, their relationship is similar to the others in the sense that it is quite unpredictable, given Hannah's attitudes and the age difference between them. Finally, in the case of the play's minor characters, we may observe the effects of unpredictability in the love affair of Captain Brice, Lady Croom's brother, and Mrs Chater, which is indirectly responsible for the death of the latter's husband: in order to remain close to Mrs Chater, the captain takes her and Mr Chater to a botanical expedition to Madagascar, where Mr Chater eventually dies of a monkey bite. Hence, by foregrounding the unpredictable and problematic effects of romantic and sexual attraction, the play makes human emotion 'the attraction that Newton left out' (p. 104), suggesting that accurate long-term predictions concerning both nature and human affairs cannot be made.

Although the play suggests that emotions often have unpredictable consequences, unpredictability in itself does not have the power to reverse the direction of time's arrow. This is clearly evident in the way in which Stoppard employs the idea of entropy as a force to which all physical existence is ultimately subjected. In addition to making the observation about the impossibility of stirring the jam back to its original form, Thomasina notes how energy used for work becomes unavailable for reuse. 'Newton's equations go forwards and backwards', she explains, 'they do not care which way. But the heat equation cares very much, it goes only one way. This is the reason Mr Noakes's engine cannot give the power to drive Mr Noakes's engine' (p. 123) — a fact that makes Septimus worry about the world meeting its end through heat death. What is more, the link between the direction of thermodynamic processes and time is evident in Valentine's observation about the cooling of hot liquid. 'Your tea gets cold by itself', he notes, 'it doesn't get hot by itself' (p. 110). Eventually, the 'tea will end up at room temperature', with the consequence that 'what's happening to your tea is happening to everything everywhere' (p. 110). Mr Noakes's steam engine and tea are here used as examples of the familiar process of the degradation of energy from its usable form to an unusable one until the universe has reached a thermodynamic equilibrium.

Because of the anxiety this thought arouses in him, Septimus spends the rest of his life trying to find evidence against the 'Frenchified mathematick' (p. 93), with whose implications Thomasina's work aligns itself. As Hannah notes, he is aiming for 'the restitution of hope through good English algebra' (p. 93). Thus, Septimus is trying to mathematically prove that the world is not destined for heat death. The play, however, suggests that such a fate is inevitable. In addition to Valentine's explanation of the implications of the second law of thermodynamics — and the fact that Septimus's classically educated mind goes mad while trying to deal with Thomasina's mathematics — *Arcadia* employs symbolic means of arguing for the inevitability of heat death. For instance, we learn that Thomasina meets her end in a fire after she waltzes with Septimus. Similarly, fire destroys things that are valuable from the viewpoint of human knowledge: Septimus burns an unread letter written by Byron that might have contained important information for latter-day scholars such as Bernard, and Thomasina laments the destruction of the library of Alexandria by fire.

At the same time, however, the play makes heat and fire symbols of not only destruction but also physical attraction, the driving force of human relationships. For instance, Thomasina describes the findings of the latest contemporary French mathematicians as follows:

THOMASINA	Well! Just as I said! Newton's machine which would knock our atoms from cradle to grave by 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.
LADY CROOM	Of what?
THOMASINA	The action of bodies in heat. (p. 118)

Whether intended or not, Thomasina’s reference to thermodynamics humorously captures the primary motivation behind the actions of the play’s characters. As observed above, unlike the predictable motion of celestial bodies in Newton’s theory of motion, the action of human bodies in heat is more or less unpredictable and random. As metaphorically thermodynamic processes, sex and death, creation and destruction, thus represent the two primary forces that ceaselessly shape the form of humankind.

On this view, fire — and heat in general — is a double symbol through which the play represents two opposite yet complementary qualities that are inextricably intertwined with each other. On the one hand, just as death is the eventual fate of every organic being, a part of human knowledge is bound to be destroyed through the contingencies of history, such as the fire in the library of Alexandria. On the other hand, thermodynamic processes continuously create new structures, as suggested by the way in which Septimus consoles Thomasina, who grieves at the fate of antiquity’s great library. He explains to her that human knowledge can be not only discovered but also rediscovered:

> We shed as we pick up, like travellers who must carry everything in their arms, and what we let fall will be picked up by those behind. The procession is very long and life is very short. We die on the march. But there is nothing outside the march so nothing can be lost to it. The missing plays of Sophocles will turn up piece by piece, or be written again in another language. Ancient cures for diseases will reveal themselves once more. Mathematical discoveries glimpsed and lost to view will have their time again. (p. 57)

Indeed, as the fact that Valentine rediscovers Thomasina’s ideas shows, the play proposes that metaphorically thermodynamic processes such as history and relationships are characterized by endless cycles of beginnings and ends. Moreover, Hannah’s research on the history of Sidley Park and Bernard’s work on Byron reveal how significant new information emerges from the past, even though the past cannot be captured in its entirety.[29] This is why Valentine's description of the fractal pattern based on Thomasina's mathematics, 'The Coverly Set', is suggestive: 'In an ocean of ashes, islands of order. Patterns making themselves out of nothing. […] Each picture is a detail of the previous one' (p. 107). The fact that he compares history to a fractal set emphasizes the idea of continuity throughout the ages: like a fractal set that through iteration continuously gives birth to novel self-similar patterns, history generates information that generates more similar information in an autocatalytic fashion.[30] This echoes Gleick's repetitive syntactic patterns in *Chaos*, which through their linguistic form accommodate the idea of self-similarity.

From the viewpoint of the characters, this realization is deeply meaningful because it allows them to see an ordered pattern emerging out of the ocean of ashes. It is in this regard that chaos theory, with its emphasis on unpredictability and irregularity, teaches Newtonians such as Bernard and Hannah a lesson: while the former relies on the principles of linear thought only to arrive at the wrong conclusion regarding Byron's activities, the prejudiced view of the latter prevents her from seeing that the shift from controlled

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[29] To be sure, as Susanne Vees-Gulani points out, the very uncertainty that plagues the research of Hannah and Bernard on Sidley Park's past (Bernard, for instance, erroneously thinks that Byron shot Ezra Chater, while Hannah falsely conjectures that there is a picture representing Septimus as a hermit in a picture book) suggests that the play compares history to a complex system about whose past it is impossible get totally accurate information because of the sensitivity of the system to initial conditions. Susanne Vees-Gulani, 'Hidden Order in the "Stoppard Set": Chaos Theory in the Content and Structure of Tom Stoppard's *Arcadia*', *Modern Drama*, 42 (1999), 411–26 (pp. 420–21).

[30] As Vees-Gulani notes the image of self-similar fractals is present not only in the contents of Stoppard's play, but also in its structure in which the events of two historical periods mirror each other: Thomasina and Valentine work on similar mathematical problems, both periods are occupied by questions related to sex and literature, the garden of Sidley Park is undergoing changes in the past as well as in the present moment, certain images such as the apple leaf and a tortoise appear in both periods, and there are parallels between characters such as Augustus (Thomasina's brother) and Gus. Vees-Gulani, pp. 416–19.

regularity to controlled irregularity evident in Sidley Park's landscape during the early nineteenth century should not be interpreted as a sign of a qualitative decline (Demastes, pp. 99–100). Hence, Bernard learns not to needlessly impose rigid interpretative schemes on the complexity of reality, and Hannah is given the opportunity to learn to value intuition and feeling as elements that complement rather than oppose order and logical thinking, proving that 'what we once considered the work of lunatics, lovers, poets, irregular geniuses, and fantasists, now appears to be the work of consummate realists' (Demastes, p. 101).

Septimus too is unable to see the creative side of chaos and time's arrow, because he understands entropy only in terms of eventual annihilation. 'When we have found all the mysteries and lost all the meaning,' he laments, 'we will be alone, on an empty shore' (p. 132). For Valentine, however, although the world may appear to be chaotic — and thus meaningless — from the viewpoint of humankind, it is possible to find patterns that give it a sense of meaning. 'It's all very, very noisy out there', he notes,

Very hard to spot the tune. Like a piano in the next room, it's playing your song, but unfortunately it's out of whack, some of the strings are missing, and the pianist is tone deaf and drunk — I mean, the *noise*! Impossible!' (p. 66; emphasis original)

The comparison between music and the organization of the world in this passage obviously foregrounds the sense of disorder experienced by the characters, but as the other references to music in the play suggest — the dances of Septimus and Thomasina, and Gus and Hannah — disorder tends to give rise to highly organized and unpredictable structures. As noted above, the play shows that it is possible to observe the existence of meaningful patterns in history, and Valentine's own work in biology — his work on grouse populations is ultimately based on Thomasina's 'New Geometry of Irregular Forms' (p. 63) — shows that a sense of continuity is by no means absent from science, even though information is lost from time to time. Underlying the complexity of the world's information, then, is the kind of order that the characters experience as personally meaningful.[31]

Another important point about Valentine's observations in the above passage is that because of the noisiness of information, we are bound to rely not only on reason but also on our intuition. Answering Hannah's question concerning how to deal with the data of the real world, Valentine states that 'you start guessing what the tune might be. You try to pick it out of the noise' (p. 67), thus suggesting that in order to make sense of the complexity of the world, reason must be united with intuition. Indeed, Thomasina, Bernard, Hannah as well as Valentine himself proceed in their research by making intuitive guesses that prove to be wrong and right. In the context of our discussion on the status of chaos theory as a scientific phenomenon, this clearly links the Romantic attributes of subjectivity and intuitiveness to the science, both recalling Gleick's portrayal of scientists as intuitive solitary geniuses and picturing chaos as an approach to reality that harmonizes intellect and emotion.

Finally, I would like to point out that even though the play suggests that humankind must eventually yield before the second law of thermodynamics, Stoppard nevertheless grants some of his characters the ability to make moral choices. In this way, he implies

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[31] Heinz Antor notes that it would not be justified to label *Arcadia* a poststructuralist play that cynically denies the possibility of ever arriving at truth and meaning: although the characters experience difficulties in their search for knowledge, their efforts are valuable in themselves, regardless of whether they manage to achieve the knowledge or not. Heinz Antor, 'The Arts, the Sciences, and the Making of Meaning: Tom Stoppard's *Arcadia* as a Post-Structuralist Play', *Anglia: Zeitschrift für Englische Philologie*, 116 (1998), 326–54 (pp. 351–52). This is obviously what Hannah means when she tells Valentine that 'it's *all* trivial – your grouse, my hermit, Bernard's Byron. Comparing what we are looking for misses the point. It's wanting to know that makes us matter' (106; emphasis original).

another means of creating meaning in a universe ruled by blind and impersonal physical forces. This is most evident in the case of Septimus, who in terms of his relations to the opposite sex is very much a Byronic character: he is the lover of both Mrs Chater and Lady Croom, and, even though brilliantly intelligent, does not seem to waste time on pondering the moral aspects of his behaviour. However, although there clearly is sexual tension between him and Thomasina, he chooses to resist the temptation of introducing her to knowledge other than the purely intellectual kind. He does kiss her in the final scene but refuses to accept Thomasina's invitation to follow her to her room:

THOMASINA	I will wait for you to come.
SEPTIMUS	I cannot.
THOMASINA	You may.
SEPTIMUS	I may not.
THOMASINA	You must.
SEPTIMUS	I will not. (p. 136)

Presumably, in his first two lines in the passage, Septimus refers to his obligations towards Thomasina as her tutor. The third line, however, shows that he chooses to make a definite moral choice based on his free will. In this way, then, Stoppard foregrounds the individual's ability to make moral choices in difficult situations. As I argued in 2.2.2, in *Hapgood* the highest virtue is found in the individual's moral responsibility towards loved ones. From the viewpoint of the question of free will, Septimus's act of making a moral choice can therefore be seen as a small but significant means of experiencing a sense of freedom in a universe heading towards a certain end in the form of heat death.

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The above two analyses show how chaos theory has been represented as a distinctively Romantic phenomenon in James Gleick's *Chaos* and Tom Stoppard's *Arcadia*. From the viewpoint of rhetoric, a marked feature of Gleick's book is the link it establishes between the portraits of the various scientists and their ideas. These portraits can be seen as figures of description that metonymically link the personal traits of the scientists to the actual science in question, ascribing both the individual and the science with equally revolutionary status. Gleick's description of the scientists' ideas in turn employs figurative language that seeks to accommodate them linguistically. For instance, using figures of repetition such as coenotes, gradatio, and epizeuxis, Gleick describes chaotic systems' sensitivity to initial conditions and their self-similar structures. At the same time, he sees in chaos theory the validation of the logic of both/and and like Fritjof Capra and Gary Zukav in chapter 1, uses synoeciosis in order to exemplify how chaos theory regards chaos and order as complementary rather than opposite qualities.

Focusing on the relationship between human perception and the world, Stoppard's play also presents chaos as a Romantic phenomenon. Like Gleick's book, it builds a bridge between chaos and order, and suggests that chaos theory offers us the conceptual tools for their reconciliation. The reconciliation of the opposites is especially evident in Stoppard's imagery and the structure of his play. For instance, while fire functions as a symbol for the opposite yet mutually inclusive qualities of creation and destruction, the two dances, which link the two historical periods, suggest the unification of intellect and emotion. Moreover, it is Stoppard's characterization that also contributes to this suggestion: many of the characters either understand or learn to understand that a proper scientific attitude does not rule out the role of intuition in the production of knowledge but acknowledges its importance.

3.4 Chaos Theory and Complexity: Conclusion

In this chapter I discussed the representation of chaos theory and complexity in contemporary popular science writing and literature, focusing especially on how my chosen material treats the relationship between chaos and order. Both popular science and literature emphasize the human relevance of chaos and use the insights of the field to explore the relationship between nature and humankind, as well as particular philosophical issues, such as the problem of determinism and free will.

I began my analysis by considering the link popular science writing and literature establish between nature and humankind. Then I showed how the rhetoric of Ilya Prigogine and Isabelle Stengers supports their reconciliatory effort of uniting the two and how Prigogine's later work seeks to address the implications of irreversibility for human identity by grounding existence in temporal processes. For Paul Davies, on the other hand, the discoveries of chaos and complexity reconcile chance and determinism, thus offering us a distinctively holistic philosophy of both nature and humankind. In the same vein, Stuart Kauffman detects in complexity a scientific basis for a holistic outlook on life that foregrounds the idea that as products of similar processes of self-organization, the world and humankind are inseparable. In this way, then, popular science writing stresses the importance of the ideas of chaos theory and complexity studies for a better understanding of human knowledge and identity.

In terms of the figures of speech used in the above writers' arguments, perhaps the most notable characteristic is that they often have a distinctively reconciliatory function. As such, they link the arguments to the more general discussion about postmodernism's reconfiguration of various fundamental binary oppositions. Especially the umbrella terms, incremental series and double hierarchy arguments, antimetaboles, and antitheses used by Prigogine and Stengers, Davies, and Kauffman seek to give a rhetorically powerful linguistic form to the reconfiguration of dichotomies such as humankind and the world, humankind and time, reversibility and irreversibility, determinism and indeterminism, necessity and chance, linearity and non-linearity, self-organization and natural selection, the whole and the part, predictability and unpredictability, biology and culture, and, of course, chaos and order. In this sense, we can see that there is a link between the efforts of the popularizers discussed in the previous chapter and the ones in this chapter: just as for the former the new physics scientifically legitimates the logic of both/and, so for the latter chaos theory and the study of complex phenomena do exactly the same.

Next I discussed how contemporary fiction uses chaos as a means of examining issues in human life. I noted that writers have found in chaos and complexity a set of ideas through which they depict life as a deeply meaningful phenomenon. Connie Willis's *Bellwether*, Kate Wilhelm's *Death Qualified*, and Michael Crichton's *Jurassic Park* espouse a holistic worldview that portrays the world as a whole consisting of meaningfully connected parts. William Gibson and Bruce Sterling's *The Difference Engine* and Robert Littell's *The Visiting Professor* employ the idea about the inherent unpredictability of physical systems to foreground the unpredictability of both history and human life, thus exploring the implications of incomplete knowledge for defining the relationship between determinism and free will. While such works grant indeterminism a fundamental role in human life, Martin Amis's *Time's Arrow* presents the same topic from a different angle and suggests that history tends to be a more or less deterministic phenomenon, with similar social conditions giving birth to similar histories in a cyclical fashion. By his ironic narrative Amis shows the impossibility of reversing time in order to change history, thus portraying history as a gigantic thermodynamic process that instead of creating novelty, as the dissipative structures of Prigogine and Stengers do, merely tends to give rise to more of the same.

As regards the reconciliatory power ascribed to chaos and complexity, it is interesting to observe that literature too seeks to represent their insights as something that helps humankind understand its relationship to nature in novel ways. Instead of foregrounding strict dichotomies, then, the writers discussed above stress the notion that seemingly antithetical qualities coexist and that their coexistence produces creative rather than destructive results. Just as in the literary representation of the new physics, this indicates an underlying philosophy of complementarity, which substitutes the logic of either/or for the more holistic logic of both/and. Therefore, excluding Amis's *Time's Arrow*, the literary works analysed in 3.2 tend to regard chaos as a teacher, celebrating its ability to teach a lesson about the importance of adopting a multiperspectivist view of life. Even unpredictability, which in the form of uncertainty caused much anxiety in the minds of the characters studied in chapter 1, is on the whole regarded as a positive thing, for it appears to at least to some extent banish the demon of Newtonian, long-term determinism.

At the end of my discussion I studied a distinct cultural aspect of chaos theory by examining the link established between science and Romanticism in James Gleick's *Chaos* and Tom Stoppard's *Arcadia*. Although Gleick differs from the other popularizers discussed in this chapter by being hesitant to link science to philosophical questions, he nevertheless portrays seminal chaos theorists as Romantic geniuses in order to foreground the notion of chaos theory as a revolutionary science. However, Gleick is similar to the others in his reconciliatory drive: with their references to typically Romantic characteristics, his descriptions of chaos theorists link together conceptual pairs, such as intuitiveness and rationality, originality and tradition, and individualism and collectivity, in this way pointing to the role of the new science as a balancing factor between seemingly opposite qualities.

Stoppard’s play approaches various fundamental dichotomies in a similar fashion, establishing a connection between chaos theory’s fascination with the irregular and the unpredictable, and Romanticism’s rejection of the ideals of Enlightenment. By showing how apparently opposite qualities support rather than exclude each other, the play calls for a holistic worldview that enables humankind to see meaningful patterns at the level of both individual life and history. It suggests that even though history may override the will of individuals, the fact that humans choose to act morally in the face of the knowledge that life is heading towards a heat death is valuable in itself.

4. Evolutionary Biology and Human Nature

I now turn from chaos theory and complexity to evolutionary biology in contemporary science writing and literature. Generally speaking, the overall structure of my discussion in this chapter reflects a current major dispute in the field: the clash between the neo-Darwinism of well-known evolutionary biologists such as W. D. Hamilton, George C. Williams, John Maynard Smith, and Richard Dawkins, and the various views that have sought to challenge or modify some of the basic tenets of their theories — the so-called modern evolutionary synthesis — including those of Stephen Jay Gould and Lynn Margulis. Against this background I study how recent fiction has responded to the major claims made in this dispute, again focusing on the shared concerns of science and literature. As I show below, rather obvious concerns in the case of evolutionary biology feature the question of human identity and, to a lesser extent, the question of (evolutionary) time.

I begin my discussion in 4.2 by considering Richard Dawkins's influential version of evolutionary theory in *The Selfish Gene* and the responses to the book's controversial ideas in Daniel Hecht's *Babel Effect* and Simon Mawer's *Mendel's Dwarf* (1997). In 4.3 I examine figurative language in the arguments of the critics of neo-Darwinism through the popular evolutionary biology of Stephen Jay Gould's *Wonderful Life* and Lynn Margulis and Dorion Sagan's *What is Life?* The ideas of Gould and Margulis and Sagan are in turn examined in conjunction with four science fiction stories: Stephen Baxter's *Evolution* (2002), Greg Bear's *Blood Music* (1985) and *Darwin's Radio* (1999), and David Brin's *Earth* (1990).

4.1 From Modern to Postmodern Biology

As some critics studying the development of contemporary science have observed, a paradigm shift similar to the one that took place in physics before the Second World War has also emerged in the life sciences, which to a considerable extent has changed the scientific view of how species develop and interact. For instance, Steven Best and Douglas Kellner argue that already by the 1960s, biologists had taken a 'postmodern turn' by incorporating concepts such as holism, ecology, complexity, co-evolution, and self-organization into their models.[1] Consequently, the notion of evolution and organisms as unchanging, passive entities has undergone a marked change, since many biologists have begun to view them in terms of dynamic complexity.[2] For contemporary science writers and popularizers of science too, the emphasis given to such novel concepts has been a signal of the emergence of a new paradigm in biology. Indeed, John Brockman, who champions the notion of the third culture,[3] emphasizes the importance of complexity for the

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[1] Steven Best and Douglas Kellner, *The Postmodern Adventure: Science, Technology, and Cultural Studies at the Third Millennium*, Critical Perspectives (New York: Guilford Press, 2001), p. 118. Further references to this book are given in parenthesis.

[2] The use of the term *complexity* is by no means exclusive to biology, and it is now being employed across a wide spectrum of sciences from physics to literary studies. Hence, as Ken Baake observes, it 'works to describe a new meta-science because it sounds good in any branch of the member sciences'. Ken Baake, *Metaphor and Knowledge: The Challenges of Writing Science*, SUNY series: Studies in Scientific and Technical Communication (Albany: State University of New York Press, 2003), p. 204.

[3] It is worthwhile to pay attention to the various meanings that the concept of the third culture has acquired during the latest phase of the two cultures debate. As the Finnish philosopher Ilkka Niiniluoto has noted, Brockman uses the term to refer to the victory of the second culture (the natural sciences) over the first one (literary intellectualism and the humanities), arguing that at the most fundamental level of description, humans and human activities are properly explained only by the natural sciences. Ilkka Niiniluoto, 'Kulttuuri: yksi, kaksi vai kolme?', *Tieteessä tapahtuu*, 2 (2000), 12–15 <http://www.tsv.fi/ttapaht/002/niiniluoto.htm> [accessed 11 January 2005]

models of contemporary biology. Firstly, he argues that the idea underlying complexity in biology is that everything in the world can be understood in terms of change, and from this emerges one of the most important philosophical notions shared by the third culture scientists: that evolution is fundamentally a temporal phenomenon (‘Third Culture’). Secondly, Brockman observes that the evolution of living organisms is characterized by self-organization, which at one level replaces the concept of the so-called intelligent design, the suggestion that the development of life is directed by an intelligent entity rather than natural selection, with the idea that organisms are capable of producing complexity out of relatively simple basic principles (‘Third Culture’). Thirdly, this kind of complexity can be seen as a fundamental principle of the world rather than as an accidental feature in a strictly deterministic scheme of things. In a world in which complexity is the law, properties shared by organisms are relative to each other, meaning that biological species cannot be understood to have ‘absolute properties’ (‘Third Culture’) anymore. All in all, then, as Best and Kellner — correctly, I think — suggest, it is possible to argue that a ‘new master discourse’, which is marked by the use of vocabulary signalling complexity, dynamism, temporal change, and self-organization, has arisen to facilitate the communication of biologists studying living systems (*Postmodern Adventure*, pp. 119–120).

However, as in the case of other kinds of postmodern turns, it should be noted that the paradigm shift in biology is far from complete. This means that because the fundamental ideas of previous thought still exert a powerful influence on the current models, an interesting mixture of the old and the new characterizes scientific attitudes at the beginning of the twenty-first century. For instance, just as the principles of classical physics are still relevant to contemporary physics, so the so-called new biology of biologists such as Brian

Goodwin and Lynn Margulis has not abandoned the basic ideas on which Darwin's evolutionary theory is constructed (Best and Kellner, *Postmodern Adventure*, pp. 118–19). Thus, adhering to Best and Kellner's views on the postmodern turn in natural sciences, I want to suggest that it would be more accurate to speak about the re-evaluation of certain concepts rather than the complete discarding of them from the new paradigm.

Moreover, it is evident that this particular feature of postmodern science, the synthesis of the old and the new, has given rise to anxiety concerning the status of science as a means of producing novel insights into the mechanisms of the physical world. For instance, the pronounced reliance of contemporary biologists on Darwin's key concepts has made critics such as John Horgan express their doubts about whether evolutionary biology can in some fundamental sense be seen to be progressing beyond the implications of Darwin's version of evolutionary theory. On the basis of his controversial claim in *The End of Science* that there are no important scientific discoveries to be made anymore, Horgan argues that the message that can be read in the arguments of notable modern biologists is that Darwin has already said everything relevant about life and its development (p. 119). For Horgan, this kind of attitude is symptomatic of a deep sense of exhaustion evident not only in the writings of scientists who study evolutionary biology such as Richard Dawkins, Stephen Jay Gould, Lynn Margulis, Stuart Kauffman, and Stanley Miller but also in contemporary natural sciences in general. Although this might be true to some extent, it has to be said that the history of science has taught us to be wary of totalizing claims such as those made by Horgan. These kinds of claims, I would argue, are reflections of the anxiety caused by the paradigm shift rather than objective assessments of the status quo. 'It may indeed be the case', Best and Kellner state, 'that in some fields the *modern paradigm* is exhausted, but it takes considerable hubris to claim that science has completed its task, such that we know, in broad outlines, all that there is to know' (*Postmodern Turn*, p. 225; emphasis original).

Conjectures about the possible end of science notwithstanding, it is obvious that today's biological research is a highly contested terrain, and hence, as Best and Kellner note, the current field is 'open and indeterminate' (*Postmodern Adventure*, p. 120). On the one hand, there is the possibility that the technological application of biology may lead us towards holistic thought, in which scientific praxis is genuinely guided by responsible ethics (Best and Kellner, *Postmodern Adventure*, p. 122). On the other hand, there is the danger of an opposite development in the form of increased reductionism and commercialism, as the genetic blueprints of organisms are patented for commercial uses (Best and Kellner, *Postmodern Adventure*, p. 123).

As the following analyses attempt to show, issues in contemporary biology are inextricably linked to our perception of human identity. This is true especially in the case of evolutionary theory: recent fiction makes frequent references to the so-called selfish genes, and we often find characters and narrators offering lengthy explanations of how such genes actively and even purposely control human behaviour. By responding to the rhetoric of popular evolutionary biology, literature seeks to address the anxieties that particularly controversial theories provoke. For instance, I argue below that the response to Dawkins's notion of selfish genes in fiction may reveal something about the anxiety that is caused by the notion that humans are controlled by their constituent parts and not vice versa. Moreover, another important concern that links evolutionary biology to literature and human affairs is time. The fact that biological evolution unfolds through time raises a question about the place of humankind in the sequence of events that constitutes the development of the species: Is humankind a logical, predestined outcome of evolution, as modernism generally sees it, or merely an evolutionary accident, one of the numerous possible results of evolutionary change, as postmodern theorists of evolution such as Stephen Jay Gould claim?

4.2 Selfish Genes: Evolution and Neo-Darwinism

In this subchapter I focus on ideas that began to emerge by the so-called modern evolutionary synthesis the 1960s. Modifying and extending the insights of traditional Darwinism on natural selection, the proponents of this view, such as Theodosius Dobzhansky, Ernst Mayr, Julian S. Huxley, W. D. Hamilton, George C. Williams, and John Maynard Smith, created a theoretical model that places the gene at the heart of evolutionary theory. In short, the modern evolutionary synthesis states that natural selection operates through the competition of genes, which are considered as the primary, independent units of evolution.[4] In the zoologist Richard Dawkins's neo-Darwinist version of this model, successful genes are selfish because they are interested in producing advantageous effects on their so-called vehicle — the individual organism — without automatically supporting its survival. In other words, they are interested in the survival of genetic information rather than the host of that information.

For general audiences, this kind of gene-centric view is perhaps most familiar from the work of Dawkins. Based on the insights of the German biologist August Weismann (who was one of the founders of modern genetics during the latter half of the nineteenth century), the neo-Darwinist thinking of the 1930s, and the theories of Hamilton and Williams in the 1960s, the notion of the selfish gene represents Dawkins's development of Darwinian

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[4] Hans-Jörg Rheinberger and Staffan Müller-Wille, 'Gene', in *Stanford Encyclopedia of Philosophy*, online edn, ed. by Edward N. Zalta, 2004 <http://plato.stanford.edu/entries/gene> [accessed 31 July 2007]

evolutionary theory. He explains the concept in John Brockman's *The Third Culture* as follows:

The selfish-gene idea is the idea that the animal is a survival machine for its genes. The animal is a robot that has a brain, eyes, hands, and so on, but it also carries around its own blueprint, its own instructions. This is important, because if the animal gets eaten, if it dies, then the blueprint dies as well. The only genes that get through the generations are the ones that have managed to make their robots avoid getting eaten and succeed in living long enough to reproduce.[5]

Although Dawkins has been criticized for focusing solely on the gene as the primary unit of natural selection — one of his most ardent critics being the moral philosopher Mary Midgley[6] — his view is that such reductionism is justified if we want to describe the enormous effect genes have beyond the bodies of organisms. He refers to the notion that the genetic constitution of the organism affects not only its body, as traditional Darwinism argues, but also the world outside that body by the concept of the extended phenotype ('A Survival Machine'). For instance, a lake could be considered as the phenotypic effect of a beaver's genes:

Something like a beaver dam causes a flood, which creates a lake, which is to the benefit of the beaver. That lake is an adaptation for the beaver. It's an extended phenotype. There are genes for big lakes, deep lakes: lake phenotypes have genetic causes. You can build up to a vision of causal arrows leading from genes and reaching out and affecting the world at large. ('A Survival Machine')

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[5] Richard Dawkins, 'A Survival Machine', in *The Third Culture: Beyond the Scientific Revolution*, ed. by John Brockman (see Brockman, above) <http://www.edge.org/ documents/ThirdCulture/j-Ch.3.html> [accessed 11 January 2005]. Further references to this chapter are given in parenthesis.

[6] Midgley accuses the selfish gene theory of reductionism because it tends to explain the individual organism from the viewpoint of its genes, thus making the gene the primary agent in evolution. See, for instance, *Evolution as a Religion* and *The Myths We Live By* (London: Routledge, 2003).

In Dawkins's neo-Darwinist vision, then, genes have a very long reach. In order to survive they have built themselves robotic survival machines — his metaphor for individual organisms — that mould their environment in accordance with their genetic instructions.

4.2.1 The Biology of Altruism and Selfishness

Dawkins presents the idea of the selfish gene in more detail in the eponymous bestseller, which is a deliberately provocative effort to present evolutionary theory from 'a gene's-eye view'.[7] Using the Necker cube — a cube that produces the optical illusion of flipping back and forth, depending on which part of the cube the eye focuses on — as a visual metaphor for a situation in which the same object can be viewed from different angles, he suggests that evolution can be approached from the viewpoints of both the individual organism and its constituent genes. For Dawkins, the viewpoint of the gene represents a new vision of evolution in contrast to the traditional portrayal of the same process from the viewpoint of the individual organism (pp. x–xi).[8] Much of the controversy surrounding the book appears to stem from Dawkins's simple yet effective revision of the relationship between the organism and its genes: rather than presenting the latter at the service of the former, he inverts the hierarchy by suggesting that the former is a survival machine programmed by

[7] Richard Dawkins, *The Selfish Gene* (Oxford: Oxford University Press, 1976; 1989), p. x. Further references to this book are given in parenthesis.

[8] In the 1989 edition of his book, Dawkins notes that the Necker cube metaphor 'misses […] completely' (p. xi) the fact that the new is vision is more valuable than the old one because of its sheer explanatory and imaginative power.

the latter.[9] This inversion reflects a notable characteristic in post-Darwinian biology: instead of being inextricably linked to the individual organism, 'the locus of biological individuality has become [increasingly] ambiguous'.[10]

At the heart of Dawkins's discussion in *The Selfish Gene* is the examination of the biological basis of two opposite impulses: altruism and selfishness. He asserts that this is a question with fundamental implications for our understanding of ourselves as human beings, as it 'touches every aspect of our social lives, our loving and hating, fighting and cooperating, giving and stealing, our greed and our generosity' (pp. 1–2). The pairing of antithetical qualities via synoeciosis suggests that there is a genetic basis for all kinds of human activity, including activities usually considered as being outside of the realm of biology proper, such as moral behaviour. Consequently, because the genes directing the actions of individuals are essentially selfish, Dawkins continues, it 'often turns out on closer inspection that acts of apparent altruism are really selfishness in disguise' (p. 4). In

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[9] In the context of contemporary cultural theory, this reversal has raised a question concerning agency in the modern world. For instance, N. Katherine Hayles has discussed the link between *The Selfish Gene* and post-humanism, focusing on the implications of Dawkins's metaphor for the concept of agency in the post-human. She observes that by making the gene the protagonist of his story, Dawkins reverses the traditional hierarchy between humans and their constituent genes. N. Katherine Hayles, 'Desiring Agency: Limiting Metaphors and Enabling Constraints in Dawkins and Deleuze/Guattari', *SubStance*, 30.1–2 (2001), 144–59, in *Project Muse* <http://muse.jhu.edu/journals/substance/v030/30.1hayles.html> [accessed 23 March 2005] (p. 148). Further references to this article are given in parenthesis. After noting how Dawkins's numerous analogies establish genes as 'linguistic actors' (p. 148), Hayles goes on to argue that Dawkins's 'story takes shape as a narrative told through actors who erase their own agency even as they speak. The content thematically echoes this rhetorical strategy, for this is a story about displaced agency, about a subjectivity who has the illusion of control while the real control lies with the gene who inhabits the subject and uses him for its own ends. Displacement of agency occurs on multiple levels, within humans and within the language of the text itself' (pp. 148–49). In doing so, Hayles argues, Dawkins aims to preserve the autonomy of the 'liberal humanist subject' (p. 149), while making that autonomy a characteristic feature of the selfish gene. She goes on to argue that Dawkins's decision to use such a narrative as a reflection of Anglo-American individualism pays little attention to questions of social existence or economy (p. 150).

[10] Evelyn Fox Keller, *Secrets of Life, Secrets of Death: Essays on Science and Culture* (New York: Routledge, 1992), p. 145.

this way, then, he shows that in reality there is no opposition between the two impulses: altruism is programmed by genes to benefit the actor rather than its recipient.

However, most of the persuasive power in *The Selfish Gene* derives from Dawkins's extensive use of metaphors and analogies. Individual organisms, for instance, are 'survival machines — robot vehicles blindly programmed to preserve the selfish molecules known as genes' (p. vii), the image of the robot obviously foregrounding the mechanical nature of the organisms' behaviour. By the survival machine metaphor, Dawkins also seeks to suggest a new way of viewing not just humans but all living organisms. 'We are survival machines,' he notes, 'but "we" does not just mean people. It embraces all animals, plants, bacteria, and viruses' (p. 21). What is significant in this incrementum progressing from the most complex item to the least complex one is that it does not entail any value judgment separating humans from other species. Rather, exemplifying Dawkins's critical stance on anthropocentrism, it proposes that as survival machines, living organisms are equal because their genetic material is the same, even though their building blocks, the four kinds of nucleotides, appear in different order in each.

Because the primary aim of genes is to survive by making copies of their blueprints, Dawkins argues, the genetic material of organisms is fundamentally selfish. He sees that this quality is most evident in the competitive interaction between not only organisms but also genes themselves. Therefore, Dawkins argues that 'the basic unit of natural selection is best regarded not as the species, nor as the population, nor even as the individual, but as some small unit of genetic material which it is convenient to label the gene' (p. 39). Note how he in this passage uses a descending incrementum in order to foreground the fundamental role of the gene in natural selection over the other units of selection that biology has traditionally held as the main sources of the process of evolutionary adaptation. By placing the gene as the last item of his series, Dawkins acknowledges its primary status in evolution. Hence, it is not surprising that he chooses to formulate his argument about the relationship between altruism and selfishness at the level of genes in strongly antithetical terms: ‘altruism must be bad and selfishness good’ (p. 36). At the same time, however, Dawkins seeks to reconcile this view with the fact that genes must cooperate with each other in order to survive, illustrating the competitive interaction between genes through an analogy between genetic competition and a rowing contest. Comparing individual genes to oarsmen, he pictures a situation in which the coach of the team must experiment with different crews in order to find the best combination. The best oarsmen, the coach discovers, are not best in all conditions, but their success depends on the general performance of the team (p. 38). Consequently, Dawkins concludes that ‘it is only *on average* that the best men tend to be in the winning boat’ (p. 38; emphasis original).

By basing his argument on the similarity between genes and oarsmen, Dawkins is able to reconcile two opposite views of the gene: genes as completely individual actors (‘the free, untrammelled, and self-seeking agents of life’ (p. 38)) and genes as cooperative entities sharing the same physical environment. Hence, in Dawkins’s reconciliatory view genes cooperate for the selfish end of building a vehicle for their survival. Since the gene for Dawkins is a ‘distributed agency’ representing ‘*all replicas* of a particular bit of DNA […] distributed throughout the world’ (p. 88; emphasis original), altruistic acts between organisms are in fact examples of genes assisting the replicas in bodies outside their own vehicles.

Dawkins continues to use the rowing analogy as a means taking his reductionistic argument to its logical end point: the idea that natural selection primarily takes place at the level of individual genes. This time, however, he modifies the analogy by stating that some of the oarsmen speak only German and some only English. In other words, there is a communication problem between individual members that affects the whole crew's results, but the coach remains unaware of this. Because of this, Dawkins states, 'it looks as though the coach is selecting whole language groups *as units*' (p. 85; emphasis original). Yet, rather than being concerned with the question of nationality, the coach 'is selecting individual oarsmen for their apparent ability to win races' (p. 85). In this way, he illustrates the idea that even though

> genes are selected for mutual compatibility does not necessarily mean we *have* to think of groups of genes as being selected as units, as they were in the case of butterflies. Selection at the low level of the single gene can give the impression of selection at some higher level. (p. 85; emphasis original)

The analogy now emphasizes the idea that genes 'are ultimately selected on "merit"' (p. 86), which refers to the performance of individual genes in the context of the entire gene pool. Consequently, Dawkins argues, natural selection has to take place already at the level of genes. 'It may look', he writes, 'as though the population as a whole is behaving like a single self-regulating unit. But this illusion is produced by selection going on at the level of the single gene' (p. 86). In this example, then, it is possible to see how he imaginatively inverts the relationship between the whole and the part, making the latter appear more fundamental — and hence, more real — than the former.

The constituent parts of the whole, on the other hand, Dawkins likens to controllers and 'master programmers' (p. 62). 'The genes', he writes, 'control the behaviour of their survival machines, not directly with their fingers on puppet strings, but indirectly like the computer programmer' (p. 52). After introducing this simile he goes on to discuss a science fiction story called *A for Andromeda* (1962) by the astronomer Fred Hoyle and the writer John Elliot. As in the case of the rowing team, the problem faced by Andromedans in Hoyle and Elliot's book concerns communication. The Andromedans want to expand their civilization but are unable to travel to the other parts of the universe. In order to solve this problem they use radio waves to send a single message containing instructions for building a computer in the hope of someone picking it up. The message is eventually received and decoded on the Earth, and humans build the computer without realizing that it is part of the Andromedans' plan to enslave them. From Dawkins's viewpoint, genes do exactly the same thing with the human brain as the Andromedans with their computer: not capable of directly influencing the receiver, they 'have to build a brain' (p. 54), because controlling the world through protein synthesis is too slow in an evolutionary sense. 'Like the Andromedans,' Dawkins argues by introducing another comparison, 'the genes can only do their best *in advance* by building a fast executive computer [the brain] for themselves' (p. 55; emphasis original). In terms of his discussion on the relationship between selfishness and altruism, the simile foregrounds the indirect way in which 'genes exert ultimate power over behaviour' (p. 60). Moreover, like the rowing competition analogy, it defines the relationship of the whole and the part by granting the latter the more fundamental agency.

In addition to images suggesting competition and control, Dawkins's diction helps portray evolution as a more or less merciless warfare. For instance, in the chapter 'Battle of the generations', an extended metaphor is employed to argue that the relationship between offspring and parents should be understood in terms of a genetically programmed, selfish struggle.

> The battle [between children and parents] is a subtle one, and no holds are barred on either side. A child will lose no opportunity of cheating. It will pretend to be hungrier than it is, perhaps younger than it is, more in danger than it really is. It is too small and weak to bully its parents physically, but it uses every psychological weapon at its disposal: lying, cheating, deceiving, exploiting, right up to the point where it starts to penalize its relatives more than its genetic relatedness to them should allow. (p. 131)

The terms related to warfare and manipulation underline Dawkins's argument that behind the tactics employed by the young is the genetically programmed task of preserving the genes. 'There is really only one entity', he continues, 'whose point of view matters in evolution, and that entity is the selfish gene' (p. 137), thus again inverting the traditional relationship between the organism and the gene. For this reason, 'genes in juvenile bodies will be selected for their ability to outsmart parental bodies; genes in parental bodies will be selected for their ability to outsmart the young' (p. 137). The antimetabole in this sentence epitomizes the fact that Dawkins pictures the opponents engaged in operations of mutual manipulation, with each side employing different tactics for ensuring the survival of their selfish inside passengers.

The following chapter, 'Battle of the sexes', also focuses on the portrayal of war-like relations, but this time between the opposite sexes. Although in this chapter Dawkins focuses on relationships between individuals who are not related to each other, their nature remains quite the same as in the case of parents and children:

> This view of sexual partnership, as a relationship of mutual mistrust and mutual exploitation […] is a comparatively new one to ethologists. We had usually thought of sexual behaviour, copulation, and the courtship that proceeds it, as essentially cooperative venture undertaken for mutual benefit, or even for the good of the species! (p. 140)

As in the previous chapter, Dawkins builds his argument by envisioning the body of the organism as ‘a machine blindly programmed by its selfish genes’ (p. 146). Because of differences in the production of sperms and eggs, Dawkins argues, the male and female machines are forced to employ different strategies in order to ensure the survival of their genes, whereas the actual battle between the sexes stems from their different interests in terms of achieving this goal (p. 161).

If we take a look at the diction by which Dawkins chooses to portray the relationship between the sexes, we find that, like the relationship between parents and their young, it is suggestive of an essentially manipulative partnership. For instance, sex cells aim to ‘cash in’ by employing different kinds of ‘investment’ (p. 142) strategies; males ‘retaliate’ by abandoning babies if females use ‘the tactic’ (p. 146) of going off with another male for a better genetic investment; deserted females ‘fool’ (p. 148) new males into adopting their offspring; it may ‘pay’ (p. 148) an abandoned female to raise a child on her own if the child is old enough; females refusing to copulate make themselves ‘in demand, in a seller’s market’ because of their nutritious eggs, thus being ‘in a position to drive a hard bargain’ (p. 149) before copulation; females ‘trap’ (p. 153) their potential mates by demanding that they build a nest; male genes ‘for effective deception’ are likely succeed in the gene pool, while natural selection prefers females who ‘play […] hard to get’ (p. 154) in order to learn to recognize male attempts at deception; in terms of reproduction males are ‘high-risk, high-reward gamblers’ (p. 162) who aim to produce as much offspring as possible even if it involves taking risks. Using vocabulary to a considerable extent derived from economics, Dawkins thus depicts the relationship between the sexes as a series of tactical moves aiming at the best genetic investment.

After having portrayed the relationship between individual organisms in the above manner, Dawkins returns to the question about the relationship between the individual organism and its genes in the last chapter of the book, ‘The long reach of the gene’. He notes that at the heart of his theory is ‘the tension between gene and individual body as fundamental agent of life’ (p. 234): because individual organisms appear to function well as unified wholes, biologists have traditionally aimed their focus on questions that concern them rather than DNA (p. 237). Dawkins, however, assures his readers that this is an example of a ‘truth turned crashingly on its head’ (p. 237) — in other words, he suggests that it is through the analysis of DNA that the important questions about evolution can be answered. In order to argue for a model in which the hierarchy between individual organisms and genes is inverted, he proceeds to define the functions of DNA molecules and their environment as follows:

> The fundamental units of natural selection, the basic things that survive or fail to survive, that form lineages of identical copies with occasional random mutations, are called replicators. DNA molecules are replicators. They generally […] gang together into large communal survival machines or ‘vehicles’. The vehicles that we know best are individual bodies like our own. A body, then, is not a replicator; it is a vehicle. […]. Vehicles don’t replicate themselves; they work to propagate their replicators. Replicators don’t behave, don’t perceive the world, don’t catch prey or run away from predators; they make vehicles that do all those things. (p. 254)

By using the form of antithesis in the fifth sentence of the passage, Dawkins makes a clear-cut statement about the nature of the relationship between replicators and vehicles. While both are active agents in the tasks he assigns to them, it is obvious that Dawkins regards the latter as being subjected to the activities of the former, and goes on to note that this is in conflict with the traditional view of genes 'as part of the machinery used by individual organisms' (p. 265). Indeed, Dawkins reminds his readers that 'the replicators come first, in importance as well as in history' (p. 265) and, at the end of the chapter, uses a syntactically looser antithetical formulation in order to summarize his argument: 'The individual body, so familiar to us on our planet, did not have to exist. The only kind of entity that has to exist in order for life to arise, anywhere in the universe, is the immortal replicator' (p. 266). Hence, in Dawkins's theory the primary object in Darwin's evolutionary vision, the individual organism, fades into obscurity, as it is replaced the gene, the master programmer.

Although his idea of selfish genes building survival machines for themselves portrays genes as more or less omnipotent actors, Dawkins is nevertheless not willing to paint a completely bleak picture of the individual organism's capacity for self-determination. For instance, at the end of the chapter 'Memes: the new replicators' he notes that 'one unique feature of man […] is his capacity for conscious foresight. Selfish genes […] have no foresight' (p. 200). Dawkins thus defines one important aspect of the relationship between organisms and genes in antithetical terms, suggesting that the idea of humans possessing a free will is in fact not in conflict with his reductionistic model of natural selection. This is possible, he argues, because the human brain is 'separate and independent enough from our genes to rebel against them' (p. 332), meaning that humankind's unique capacity to plan differs from the unconscious drive of genes towards 'short-term selfish advantage' (p. 200). Dawkins concludes the chapter with a vision of rebellion against the replicators:

> The point that I'm making now is that, even if we look on the dark side and assume that individual man is fundamentally selfish, our conscious foresight — our capacity to simulate the future in imagination — could save us from the worst selfish excesses of the blind replicators. We have at least the mental equipment to foster our long-term selfish interests rather than merely our short-term selfish interests. […]. We have the power to defy the

> selfish genes of our birth and, if necessary, the selfish memes of our indoctrination. We can even discuss ways of deliberately cultivating and nurturing pure, disinterested altruism — something that has no place in nature, something that has never existed before in the whole history of the world. We are built as gene machines and cultured as meme machines, but we have the power to turn against our creators. We, alone on earth, can rebel against the tyranny of the selfish replicators. (pp. 200–01)

Stylistically speaking, the passage employs the anaphoric repetition of the first-person plural pronoun to achieve the intended tone. Reminiscent of the style used in political speeches that emphasize the necessity of taking joint action, it calls for a vision of 'a society in which individuals cooperate generously and unselfishly towards a common good' (p. 3). Even though altruism is not a part of the genetic makeup of the organism, Dawkins nevertheless insists that humankind can learn to become truly altruistic through education. Hence, in Dawkins's account of humankind's evolution neither nature nor nurture entirely determines the fate of the organism — a point that seems to some extent to compromise his argument about the absolute power of the selfish gene.

Finally, from the viewpoint of its structure, Dawkins's story of evolution also seems to suggest an underlying plot in which humankind is at the end offered the opportunity to release itself from its genetic slavery. More specifically, as the mathematician and biologist Brian Goodwin observes, this plot seems to be built on the same organizing principles as the familiar story of transformation through faith in Christian theology: although humans at birth inherit original sin of whose effects they must suffer throughout their lives, they are nevertheless capable of redeeming themselves (in Dawkins, 'A Survival Machine'). Modified to suit the argument in Dawkins's theory of the selfish gene, this means that although humans are selfish by their physical constitution, their intellectual capabilities offer them a chance of subjecting physical inheritance to moral judgment.

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To sum up, focusing on Dawkins's inversion of the hierarchy between the individual organism and its constituent genes, the above analysis shows how *The Selfish Gene* mainly relies on various metaphors and analogies through which it aims to convince readers of the plausibility of the inversion. For instance, while the survival machine metaphor suggests that the whole organism is secondary in relation to its parts, Dawkins's incremental series epitomize the idea that all organisms are equal as survival machines and that the primary unit in their evolution is the gene. In the same way, Dawkins uses analogies in order to grant the gene the role of the protagonist in the saga of evolution. Moreover, a marked rhetorical feature of his discussion is the use of vocabulary that helps portray evolution as a selfish struggle for supremacy.

4.2.2 Selfishness, Humankind, and the Rebellion against the Selfish Gene

Using Dawkins's call for the cultivation of altruism through education as a point of departure for my own discussion, I now turn to analyse fiction dealing with evolution-related themes. The first novel selected for this purpose is Daniel Hecht's *The Babel Effect*, which quite explicitly examines the question about the relationship between selfishness and altruism. Hecht's novel portrays the efforts of Ryan and Jess McCloud, a scientist couple in charge of an interdisciplinary research team, to uncover the causes behind increasing global violence. More specifically, the main question they try to solve is whether violent human behaviour can be shown to have a neuropsychological basis. Their hypothesis is that there exists a so-called Syndrome E, a group of symptoms implying that individual as well as mass violence are caused by neurotoxins such as 'viral brain pathogens, endocrine-disrupting chemicals, and electromagnetic fields',[11] which imperceptibly affect the human brain. As a result, the scientists speculate, the sense of individual anxiety and alienation escalate into social fragmentation in the form of violent behaviour.

Just as in Dawkins's portrayal of the selfish gene, then, at the heart of Hecht's novel is the question what or who ultimately controls human behaviour. On the one hand, the behaviour of the species seems to be controlled from the inside by genetic factors: genes are referred to as programmers that selfishly seek to control their hosts. In this sense, the novel's representation of evolutionary biology is strongly linked to the neo-Darwinist views of scientists such as Dawkins. On the other hand, control also appears to be exerted on humankind from the outside: *The Babel Effect* continuously makes references to shady governmental projects that aim to alter human behaviour, thus employing the motif of conspiracy, a ubiquitous element in contemporary fiction dealing with scientific notions.[12] The idea of humankind as being subjected these types of control in turn raises the question about the relationship between selfishness and altruism: If individuals are to a considerable extent controlled by forces they cannot master, is true altruism at all possible? The novel does not give an unambiguous answer to this question but suggests that humankind is

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[11] Daniel Hecht, *The Babel Effect* (New York: Crown, 2001; London: Simon & Schuster, 2002), p. 113. Further references to this book are given in parenthesis.

[12] The work of Thomas Pynchon is probably the most well-known example of the link between science and conspiracy.

capable of cooperative action that stems from the same source as the selfish instinct for survival, hence agreeing with Dawkins's basic premises.

The Babel Effect approaches these questions by presenting the theories of Ryan McCloud's Genesis organization, which are based on the findings of contemporary neurological research. As the name of the organization indicates, the team seeks to explain human behaviour by studying its origin at the level of neurons, following the 'paradigm shift that had occurred in the last twenty years, as psychology moved away from traditional views of personality and behavior toward the neuroscientific perspective' (p. 12). Consequently, in accordance with the underlying assumptions of the paradigm shift, the scientists work on the basis of the hypothesis that the global increase in violent behaviour may have its ultimate origin in neural dysfunction. Neural activity and evolution are in turn linked to each other in the protagonist's mind as follows:

> Did violent behaviour result from the overstimulation of parts of the brain that triggered violent urges, or from the underactivation of neuromodules responsible for positive social behaviors?
>
> […].
>
> From there it was only a short step to instinctive drives and the genetic programs that caused them. The basic principle was simple: Evolution selected social behaviors just as it did physical characteristics. (p. 29)

In this way, the novel seeks to translate a major social problem into a scientific question ('We've gone from looking for an overview of neurological conditions precipitating violent behaviour to […] looking for the origins of huge social movements' (p. 127)). Rather than trying to assess the influence of culture on human behaviour, the research team works on the basis of the reductive assumption that it is possible to explain phenomena such as aggression by isolating the physical processes that give rise to them. In other words, the implicit supposition is that the role of biology is more fundamental as a determining factor of behaviour than that of culture.

Hence, as in Dawkins's 'nature red in tooth and claw' brand of evolutionary biology, violence emerges as something of 'a species norm' (p. 129), the type of behaviour characteristic of the human genotype. It is the incorporation of this idea that links the scientists' hypothesis to the neo-Darwinist concept of the selfish gene. To a large extent following Dawkins's representation of the relationship between the organism and the gene, the novel suggests that aggressive human behaviour derives from a specific internal source. 'Our genes program us to be selfish, to look out for our own advancement' (p. 150), as one of the scientists puts it. By using the programming metaphor, the scientist, like Dawkins, suggests that human beings are fundamentally complex machines whose actions always aim to ensure the survival of their constituent parts, the genes ('Instinctive, basic drives would always be the engine of human activity' (p. 89)). The neo-Darwinist view is introduced in similar terms by another scientist — the scientist's surname, Weissmann, is an obvious reference to August Weismann — who states that the individual organism is ultimately 'an *effective vehicle for the genes to replicate*' (p. 287; emphasis original). Thus, with genes as primary actors in the story of human evolution, the views of these scientists seek to invert the traditional hierarchy between the organism and its genes in the fashion of neo-Darwinist thought.

While its protagonist takes more or less for granted the neo-Darwinist notion of genes as active, purposeful agents in control of human behaviour, *The Babel Effect* suggests that humans are also subjected to another kind of control: control from the outside. This idea is introduced through a conspiracy motif that emerges from Hecht's portrayal of the corporate world and governmental agencies that, like neo-Darwinist genes, are ultimately driven by selfish motives. On the one hand, the Genesis organization's research on Syndrome E is financed by a company called Ridder Global Corporation, whose head, Jason Ridder, represents the stereotypical opposite of the idealistic scientist: an owner of a large pharmaceutics company, he is mainly interested in the profit gained from the hypothesis that violent human behaviour stems from a physical — and thus medically treatable — cause. On the other hand, the US government is also interested in the research team's findings: an agent monitoring the scientists' progress notes that they could be disastrous in the hands of terrorists seeking to create 'neurologically programmed assassins' (p. 109) by altering brain activity. In this respect too the novel foregrounds the idea of humans as programmable machines that often seem to act unaware of their deepest motives.

Hecht's novel thus cultivates a sense of paranoia by setting the lone protagonist against faceless, protean organizations that seek to utilize high technology as a means of controlling large populations, at the same time emphasizing his inability to link all the details together in order to see the whole picture. Eventually, Ryan begins to entertain the idea that he too is a victim of the Syndrome E, and finds himself in the middle of a Pynchonesque network of possibly interrelated factors, although, as in *The Crying of Lot 49*, readers never learn whether the conspiracy really exists in the world depicted by the novel or only in the protagonist's consciousness.[13] His sense of helplessness and doubt

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[13] In the words of Frederic Jameson, conspiracy constitutes 'the poor person's cognitive mapping in the postmodern age'. Frederic Jameson, 'Cognitive Mapping', in *Marxism and the Interpretation of Culture*, ed. by Cary Nelson and Lawrence Grossberg (Urbana: University of Illinois Press, 1988), pp. 347–60 (p. 356). As a literary device it has been used to point to the incomprehensible complexity of modern society, and is often symbolized by organizations working inside and outside governments, multinational corporations, as well as by different kinds of virtual networks. Brian McHale, *Constructing Postmodernism* (London: Routledge, 1992), p. 178. Further references to this book are given in parenthesis.

manifests itself a certain kind of mechanization, as feels he cannot relate to others as a sympathetic human being. In this respect, the protagonist's condition represents the notion that humans have begun to resemble machines incapable of ascribing 'a consciousness like our own to another person' (p. 353) and, as a result, have become unable to treat each other as human beings.

Although Hecht in this way suggests that individuals are not in control of their own behaviour, he nevertheless simultaneously introduces the idea that cooperation between the members of the species could offer a way out of the impasse of selfishness. In Dr Weissmann's view, cooperation, like selfishness, is essentially a survival strategy:

> We regard altruism and cooperation very highly. And we should — the greatest survival advantage the human animal enjoys is its penchant for social cooperation! The foundation of human societies is our *biologically based ability to cooperate*. (p. 316; emphasis original)

The novel approaches the question of cooperation through kinship recognition, which is what the protagonist's wife, Jess, studies. Her hypothesis is that the closer an individual is to another in terms of genetic makeup, the more probable it is that altruistic behaviour occurs. As a long-term evolutionary strategy the benefits of cooperation appear to exceed those of selfish behaviour: cooperation guarantees better chances of survival than selfishness because the latter often involves the risky strategy of continuously competing against the other members of the species. It is evident, however, that in the novel the relationship between selfishness and cooperation is based on the idea that the former is the cause of the latter, and in this sense the portrayal of the relationship follows closely Dawkins's argument, in which apparently altruistic behaviour serves to mask the self-seeking interests of the selfish gene. For instance, for Dr Weissmann, whose explanations

Ryan McCloud uncritically accepts, 'social cooperation is based on the selfish gene recognizing itself in other bodies and being selfishly nice to itself' (p. 317), a notion that echoes Dawkins's reconciliatory view in his rowing team analogy, and to a considerable extent defines the relationships between the novel's characters. Hence, the novel does not seek to portray altruism as willingness to perform unselfish acts but as a survival strategy designed to help the aspirations of the selfish gene.

Like Dawkins's account of the relationships between individual members of the same species, then, Hecht's portrayal of human interaction foregrounds a comparison to a game in which players seek to maximize their profit by performing various calculative moves. Thus, it is not surprising that the novel makes explicit references to game theory, a branch of mathematics that studies the selection of strategies in competitive situations:

> Games [*sic*] theory is a branch of logic that creates mathematical models of transaction between competing forces — self-interested players who want absolutely to win. The whole idea is to model observed survival strategies in nature. Animals or humans, everybody's out to win, right, everybody's selfish. (p. 330)

The best way to make sure that one wins is to play 'nice' (p. 331). This means that instead of pursuing profit aggressively, players seek to win by cooperating, thus minimizing the risks in the game. In contrast, the opposite strategy of playing 'nasty' (p. 331) means that players seek to maximize their profit by taking big risks, aiming at the partial or complete elimination of the other side in a competitive situation. For the novel's scientists, cooperation in the end is the more successful strategy of the two ('The top fifteen of the sixteen best strategies are *nice!*' (p. 332; emphasis original)).

Modelling human interaction on game theory, *The Babel Effect* explores altruism through a subplot in which Jess is kidnapped by a religious group that sees her scientific outlook as a threat to its aims. Taken to Africa, she manages to escape from her captors, but is then in danger of perishing of hunger, as she tries to find her way back through the war-torn centre of the continent. Eventually, she comes across a group of African refugees, and is fed by a young mother whose child has just died. The mother saves Jess's life by letting her drink the milk that was originally intended for the baby (p. 515). This act could be seen as a response to Jess's own kindness, since she had met her when the baby was still alive, giving them condensed milk to drink — or it might be that she feels related to Jess because Jess is African-American. As Jess's retrospective account of the event suggests, however, the mother might have performed the seemingly altruistic act in order to reduce the uncomfortable swelling of her breasts, thus being fundamentally motivated by the selfish interest of survival. The portrayal of the meeting therefore exemplifies the underlying idea that in terms of survival, it is better for genes to act nice than nasty — by choosing to help Jess, the woman improves her own chances of survival.

Similarly, the survival of Jess's husband provides us with a second instance of how the novel embraces the neo-Darwinist notion of cooperation as a selfish survival strategy. Arriving in Africa to search for his wife, Ryan is taken hostage by his wife's kidnappers, and is about to be executed when his life is saved by the group leader's right-hand man. As the man helps Ryan escape, he confesses that he is not acting out of kindness towards a representative of a different ideological position but out of desire to protect his leader from committing an ethically objectionable act that might lead to the collapse of the group (p. 489). In the man's case, then, the apparently altruistic act is motivated by ideological kinship between him and the group: by playing nice, he selfishly tries to ensure that the group's ideology — Dawkins would call this the group's dominant meme[14] — survives in the future. Hence, both this and the example above emphasize the idea that cooperation may function as an effective survival strategy when both players are allowed to benefit from the situation.

In contrast, characters that act in exceedingly selfish ways for the sake of larger profit are losers in terms of survival. For instance, Reverend Constantine, the leader of the group that tries to kill the McClouds, completely refuses to listen to Jess's advice — she attempts to help him understand that there is no fundamental conflict between the values of science and religion — and ends up committing suicide as a consequence of his unyielding attitude. Jason Ridder's right-hand man, Darion Gable, who is eventually revealed to be responsible for the murder of Ryan's colleague, also dies because he tries to eliminate his opponents by unlawful means rather than by trying to cooperate with them. Hence, the fates of these characters serve to confirm the notion of cooperation of as a maximal winning strategy for survival — the high-risk strategies of Constantine and Gable are bound to be unsuccessful in the long run, as they cause too much opposition.

Even if the novel leaves open the question about the ultimate motivation behind the action of the young mother, it nevertheless shows that goodness, regardless whether it is understood as a consequence of the nice strategy of the selfish gene or a genuine example of disinterested desire to help, is a built-in feature, just like selfishness — a notion evident in Dawkins's synoeciosis that pairs opposite behaviours. In this way, Hecht foregrounds the

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[14] For Dawkins, memes are the fundamental units of cultural inheritance that, like genes, survive through replication. 'Examples of memes', he writes, 'are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches. Just as genes propagate themselves by in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via […] imitation' (*The Selfish Gene*, p. 192).

idea that human values and belief systems ultimately derive from a distinct biological source to which they can be reduced without not necessarily deflating their significance. For instance, the Christian maxim of ethical reciprocity, 'Do unto others as you would have them do unto you', would in this view be considered as a recommendation to play nice, which in the end stems from the organization of the brain's neurons. Indeed, the end of the story presents a vision of an ethically responsible scientific praxis in which the boundary between science and religion has become erased. This vision has 'science and spirituality, the great ways of knowing, converging at last. Reverence and curiosity becoming a single impulse, as they should be' (p. 511). Thus, like Dawkins's vision of education as the salvation of humankind, Hecht's novel portrays humans holding the keys to both the damnation of selfishness and the redemption of goodness, since they stem from the same source, the brain. Yet, the willingness to give a single explanation for a wide variety of biological and cultural phenomena may constitute the most problematic aspect of the novel. Although it would be easy to imagine different kinds of social, political, economical, and environmental behaviour that cannot be reduced to the level of neural interactions, *The Babel Effect* chooses to considerably limit the range of plausible explanations by explaining the actions of its characters through a mixture of neo-Darwinism and sociobiology.

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While Daniel Hecht's characters choose to uncritically accept the machinations of selfish genes, other novels portray deliberate acts of defiance against the devious inside passengers. In Simon Mawer's *Mendel's Dwarf*, the idea that it is possible for humans to rebel against the plans of the replicators is portrayed through the theme of genetic engineering. By depicting the battle against genetic determinism as a battle between nature and technology, Mawer articulates many of the crucial anxieties that characterize the relationship between biology and technology today. The larger context of the novel's exploration of this relationship is aptly described by Steven Best and Douglas Kellner, who in their exploration of the shift from the modern to the postmodern world argue that the 'postmodern adventure', the stage of transition between the two worlds, is at one level

> a navigation through the commotion and complexity of the present, a search for order in the seeming disorder, as it maps both the disorganization of the previous forms of culture and society and their reorganization into new modes and structures. (*Postmodern Adventure*, pp. 8–9)

This characteristic, they claim, is evident especially in the case of new technologies in areas such as genetic engineering, cloning, multimedia, cyberspace, and virtual reality (*Postmodern Adventure*, p. 9). To a considerable extent, the complexity of the present moment manifests itself as both hope and anxiety, which people often project on contemporary science and technology. For instance, while contemporary medical research has discovered new ways of combating illnesses, genetic engineering, the deliberate manipulation of genetic material, continues to provoke concern about its unforeseen effects on humankind, as anticipated in the dystopian visions of writers such as Mary Shelley, H. G. Wells, George Orwell, and Aldous Huxley (Best and Kellner, *Postmodern Adventure*, p. 9).

Mawer's novel is a more recent example of fictitious responses to the ambiguities of Best and Kellner's postmodern adventure, as it deals more or less directly with the various implications of the manipulation of genes. Because it thus focuses on the relationship between the individual and the gene, the book is also an apt choice to place alongside Dawkins's influential theory about the selfish gene. Its protagonist and narrator, the geneticist Benedict Lambert, is a descendant of the Moravian monk Gregor Mendel, whose experiments with peas led to the birth of modern genetics after his work was rediscovered in 1900. Lambert suffers from achondroplasia, a hereditary condition in which the growth of body's long bones is restricted and which thus produces short limbs in individuals — in other words, Lambert is a dwarf. As a geneticist and social failure, he is obsessed by his own condition and tries to locate the gene responsible for dwarfism in order to get to the cause of his troubled existence. The story of Lambert's search for the gene is linked to a subplot that features his relationship to the suggestively named librarian Jean Piercey, an object of his sexual fantasies. Because Jean and her abusive husband, Hugo Miller, are incapable of having children, she asks Lambert to artificially impregnate her. Hugo eventually finds out that Jean has given birth to Lambert's baby and, embarrassed by the fact that he is now a surrogate father to a dwarf's child, kills the baby.

In addition to narrating his own story, Lambert focuses at length on both the life of his distant ancestor and the general history of genetics. Through the juxtaposition of the two scientists' lives, the novel makes the histories of Lambert and Mendel mirror each other: both study inheritance and are obsessed by the desire to find a solution to a biological problem; both escape the restrictions of their environment through education; both have a relationship with a married woman; and both make a significant scientific discovery that earns them fame. The juxtaposition of Lambert's story and the general history of genetics in turn allows Mawer to study genetic engineering from the viewpoint of ethics, thus raising questions about the ways genetic engineering has increased humankind's mastery over natural processes: Is genetic research ethically acceptable if its practices are to a large extent determined by the values of the commercial world and advertising? Should genetic engineering be used as a means of perfecting humankind? At another level it poses one of the most debated questions in the history of the life sciences: What are the roles of nature and nurture in determining human behaviour?

Through these questions Mawer's novel draws our attention to the ambiguous implications of a situation in which humankind is about to significantly increase its control over the genetic makeup of the species. On the one hand, genetic engineering could be considered one of the means of rebelling against the selfish gene, since it allows humankind to not only to control genetic material but also to change it according to its own ends. On the other hand, *Mendel's Dwarf* suggests that it could become a weapon of oppression rather than an instrument of liberation under certain social and ideological circumstances. Hence, through the form of narrative fiction, it considers the implications of the ideas that Dawkins discusses in his manifesto of rebelling against the tyranny of the selfish replicators.

The novel examines this situation by setting scientific mastery against the notion of a universe ruled by chance. By Lambert's continuous self-observation readers are presented with a view of nature as a set of indifferent processes that blindly operate on hapless individuals. 'No-one is to *blame*', Lambert muses, 'that I possess this stunted, contorted body, this hideous prison of flesh and flab and gristle? You can only blame the malign hand of chance.…'[15] As a result, he envisions life as an essentially absurd phenomenon that is

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[15] Simon Mawer, *Mendel's Dwarf* (London: Random House, 1997; London: Transworld, 1998), p. 12; emphasis original. Further references to this book are given in parenthesis.

governed by chance for no other purpose except the continuation of the genetic line. 'You are all victims', Lambert states in a distinctively Dawkinsian vein, 'of whatever selection of genes is doled out at that absurd and apparently insignificant moment when a wriggling sperm shoulders aside its rivals and penetrates an egg' (p. 30). The narrator himself, of course, functions as evidence for his own claims: he is 'a mutant' (p. 20), an accidental end product of miscopied genetic information. Similarly, Lambert's comments on Mendel's work suggest that the latter's groundbreaking discoveries established genetic make-up as the primary factor determining the lot of humankind: 'Mendel handed us our origins and our fate for examining, and no-one took any notice…' (p. 12). Evident in these passages, then, is the view of existence as a biologically — or, more precisely, as a genetically — determined phenomenon.

In terms of my discussion on the novel's relationship to the idea of selfish genes, it is interesting to note that like Dawkins, Lambert locates the roots of this kind of determinism at the level of genes. His description of DNA follows Dawkins's inversion of the traditional hierarchy between the organism and the gene, the whole and the part, with the latter effectively displacing the agency of the former:

> You must understand that the DNA isn't *carrying* the message: the message is an integral part of the molecule. The message *is* the molecule. And just so, there isn't a fundamental *you* that stands outside all this and watches it from some exalted viewpoint, like a reader looking at a book. It's much stranger than that. You watch it with the machinery that it has created. You understand it — or fail to — with the machinery that it has created. That's the point. The medium really is the message. (p. 123; emphases original)

In contrast to the primary agent, the gene, the individual appears to be almost like a disembodied pattern of information, as suggested by the metaphor that compares the physical medium to a message and the simile likening individual organisms to readers.

Moreover, Lambert's repetition of the word *machinery* strengthens the impression of genetic determinism as a kind of mechanistic phenomenon: the individual appears to be nothing more than the sum of the parts that together determine how the whole functions.

Locating the origin of chance at the level of genes, Lambert consequently seeks to describe himself in reductive scientific rather than metaphysical terms. 'I am, in good Mendelian fashion, a simple dominant', he explains, 'I might have 50 per cent of my genes in common with each of my parents, but I don't share that particular one with either of them. I couldn't have come from them without a mutation…' (p. 21). In spite of the detached tone of description, Lambert is haunted by questions of origin and purpose: although seeming to accept that human existence is ultimately subject to chance — the tyranny of genes — he longs to discover his past in order to understand his present condition. This is evident not only in Lambert's self-observation but also in the novel's structure, which juxtaposes the now of his life with the then of his genetic past, the life of Mendel. For instance, just as Lambert's hopeless future would appear to follow from his pitiable physical condition, so Mendel's chances of breaking free from the constraints imposed on him by his environment would have seemed non-existent at the time of his birth. 'The future would have been no more than a continuation of the past', Lambert comments on Mendel's probable future, 'not subject to change. You accepted your lot, and visited the family graves regularly just to see what acceptance meant' (p. 41).

Instead of predicting Lambert's fate, however, his genetic past — in the form of his ancestor's life — shows a way out. Just as Mendel escapes the dullness of peasant life by first gaining admittance to grammar school and then to theological college, so Lambert discovers education in biology as a means of evading some of the less appealing alternatives, such as the ones suggested by the fact that his great grandfather earned living running 'a freak show' (p. 65) and that the grandfather had later become a eugenicist. In the prejudiced eyes of the rest of the society, submitting to such a past appears as the only possible future for Lambert (his study counsellor suggests that he join the circus instead of pursuing a career in biology). From the viewpoint of the opposite sex, Lambert is doomed to fail because of his unattractive physical appearance: he confesses his love to a girl only to hear that a relationship between them would be 'impossible' (p. 60). In this way, the novel suggests that social prejudice may in fact be a larger obstacle than genetic inheritance in defining individual development: despite his unappealing genetic make-up, Lambert is able to work his way up on the ladder of social existence but feels alienated from the rest of society because of the disappointments in his personal life.

As such, Lambert's character conforms to the stereotypical characterizations of talented scientists as social failures who often use their scientific knowledge as a means of getting even with society. Since this kind of revenge takes place by controlling the world outside the self, the characterization thus establishes a link between control and scientific knowledge. In fact, it represents one of the most powerful ways of depicting the consequences of the use of scientific knowledge as an instrument of control in Western mythology. In his *Prométhée, Faust, Frankenstein: Fondements imaginaires de l'éthique* (1996), the French philosopher Dominique Lecourt studies scientific knowledge through three mythical characters in Western culture: Prometheus, Faust, and Frankenstein. He is fascinated by the paradox that characterizes their relationship to contemporary society, noting that they evidently continue to haunt our imagination, although our culture itself has lost interest in its fundamental myths.[16] For instance, what makes Shelley's *Frankenstein* so relevant at the beginning of the twenty-first century is that the story voices humankind's anxieties about the technological applications of biological research by focusing on the issue of mastery: while his abilities as a scientist give him an opportunity to control natural processes, Victor Frankenstein is unable to predict the consequences of his actions.[17] Similarly, in the case of contemporary biotechnology, scientists appear to experiment without always being able to predict the outcome of their experiments (Best and Kellner, *Postmodern Adventure*, p. 11).

In terms of wanting to master nature, Lambert is definitely a Frankenstein-like character. Consequently, while a self-acknowledged victim of 'the tyranny of chance' (p. 16), he also represents the human desire to attain mastery over the seemingly uncontrollable processes of evolution and genetic inheritance. Against the bleak biological determinism suggested by Lambert's views on nature, then, the novel equates genetic engineering with the ability to make choices concerning things that previously were considered beyond human control. This idea is emphasized by yet another parallel between Mendel and Lambert. A humorous remark by the former creates a point of comparison for the latter's studies on the human genome. Explaining the principles of breeding to a friend and admirer called Frau Rotwanger, Mendel notes that 'I, Gregor Mendel, am the only one who commands the matings here. No pea may mate without my consent. In nature it is blind chance that determines what crosses take place. Here it is I' (p. 105). Similarly, scientific

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[16] Dominique Lecourt, *Prometheus, Faust ja Frankenstein: Tieteen etiikka ja sen myyttiset kuvat*, trans. by Kaisa Sivenius (Helsinki: Gaudeamus, 2002), pp. 9, 23.

[17] Lecourt, p. 27.

knowledge gives Lambert an opportunity to overcome chance when he artificially impregnates Jean: he now 'has the possibility of beating God's proxy and overturning the tables of chance. He can choose' (p. 250). Ultimately, the fact that Lambert's work aims at the mastery of selfish genes is what makes his role so significant.[18] In fact, Lambert's desire to locate the gene for achondroplasia is characterized by the biblical undertone of Dawkins's idea of the rebellion against the selfish genes: humankind turns against its oppressive creators in the hope of attaining salvation through technology.

Humankind's increased mastery over evolutionary processes is also evident in the choices made by the other characters. Seeking to escape her violent husband, Jean has sex with Lambert and becomes pregnant. In this way, *Mendel's Dwarf* explores the ethically problematic grounds of making choices concerning the control of reproduction. Jean's decision is solely motivated by her not wanting to take the risk of giving birth to the same kind of 'monster' as Lambert is. The fact that the abortion episode is placed just before the beginning of Lambert's digression on the history eugenics suggests that society has already to some extent legalized the means that can be used to eradicate individuals and characteristics that are unacceptable from the viewpoint of the majority.

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[18] As Mary Midgley notes, the idea that humankind may learn to control the all-powerful genes has made the science of genetic engineering alluring to imagination: '[That the whole has primacy over its parts] has been obscured in recent times by the enormous interest that was naturally, and rightly, generated by the discovery of DNA's role in reproduction. A more profound cause of it, however, is the symbolism — the uncontrolled tangle of metaphors that has grown up around that discovery, building up the notion of genes as possessed of an almost magical, spontaneous power. This exciting idea has been made even more seductive by the hope that, through genetic engineering, we ourselves may be able to dominate these powerful genes and thus become the controllers of the whole system'. Mary Midgley, *Science and Poetry* (New York: Routledge, 2001), p. 4.

By exploring the ethical grounds on which choices such as abortion are made, then, the novel points to the potential dangers of ethically uninformed scientific practice. This can especially be seen in Hugo Miller's confrontation of Lambert:

> Well, what about genetic disease, then? What about this cystic fibrosis we all hear about? […]. Don't we keep all these people alive and allow them to breed and doesn't that mean that their mutations are kept in the population? […]. What about natural selection, eh? Haven't we eliminated natural selection? We keep people alive when in the wild they'd be eliminated because they're weaker, don't we? (p. 114)

Implicit in Hugo's questions is the idea that evolutionary competition, 'nature red in tooth and claw', should be allowed to take place in society as well. Hence, the passage suggests that for the likes of Miller, the level of genes functions as a model for the ethical principles governing the level of society. Through this analogy the novel proceeds to examine one of the most problematic questions concerning the relationship between science, technology, and ideology: While technology has to some extent eliminated natural selection, is it possible that technological applications of scientific knowledge could be simultaneously used as a means of extending the principles of natural selection to society?[19]

Mendel's Dwarf engages in this discussion by showing how certain dominant ideas in our culture are ruthless. Lambert's society, for instance, is obsessed by the idea that a

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[19] Such analogies are worrisome because they obviously support the notion of social existence as a competition in evolutionary fitness. In her critique of Dawkins's thinking, Mary Midgley argues that Dawkinsian sociobiology buttresses social Darwinism, which she calls 'the unofficial religion of the West'. Mary Midgley, 'Selfish Genes and Social Darwinism', *Philosophy*, 58.225 (1983), 365–77, in *The Royal Institute of Philosophy* <http://royalinstitutephilosophy.org/articles/ midgley_genes.htm> [accessed 18 March 2005]. Further references to this article are given in parenthesis. For Midgley, there is a fundamental contradiction in Dawkins's formulation of the relationship between the aims of selfish genes and human aspiration to altruism. From her viewpoint, Dawkins's claim that culture could diminish the power of selfish genes is ultimately self-defeating: because opinions are shaped by powerful memes, which 'are just as ruthlessly selfish as genes' ('Selfish Genes'), there seems little chance for human will to change things. In neo-Darwinism and sociobiology, she concludes, we 'have no real alternative to the paralysis of complete despair' ('Selfish Genes').

person must be of certain height in order to be classified as normal. Thus, given the fact that the protagonist of the novel is a dwarf working in genetics, the idea of genetic engineering as a means of perfecting human existence appears in an ironic light. As Lambert's lengthy expositions of the history of genetics make clear, under certain political and ideological circumstances, the lives of 'abnormal' individuals such as he himself could be terminated before birth. In other words, Lambert's groundbreaking work in genetics, the identification of the gene that causes achondroplasia, could be used to eliminate difference in society. Hence, even though his scientific knowledge enables him to display mastery over evolutionary processes, culture's ideological content ultimately determines how that knowledge is going to be used. This makes the novel's representation of contemporary biology ambiguous: while it offers exciting possibilities for improving the human condition, genetic engineering is at the same time vulnerable to misuse. If choices in such matters are based on deeply ingrained prejudices rather than on views that accept difference, new technologies could help create a dystopian society built on totalitarian principles.

In the end, the decision of Hugo Miller to kill Jean's child can be interpreted to symbolize the consequences of such prejudices. Because of his inability to tolerate anything abnormal, it is Miller who is ultimately the monster rather than Lambert or his creation. At the same time, however, Lambert is not without fault either: both Jean — who receives brain damage while giving birth — and the baby are affected because of his obsession of beating the blind hand of chance and the prejudices of society by passing on his genes. Aided by the technology of genetic engineering, Lambert does what his selfish genes tell him to do, that is, prevails over a rival male and continues his own genetic lineage. 'I confess to a feeling of mild elation', he states at the end of the story, 'Not triumph, nothing excessive: but the plain feeling that I have won. Benedict had achieved his child and passed his precious genes on to the next generation' (p. 296).

The end of the novel thus reflects the ambiguities that surround contemporary genetic engineering. On the one hand, Jean's permanent brain damage seems to suggest that genetic engineering may have unpredictable consequences. On the other hand, it is not science that leads to the ultimate tragedy, the murder of the baby, but the views of the prejudiced society. In fact, it is the technological application of science that allows Lambert to feel normal:

> Smiling, the nurse bent down towards me and for a moment the scrap of flesh writhed in my arms. I felt what? I must confess that I felt something remarkable. But what, exactly? Well, I felt like my father. Is that absurd? Perhaps. Bathetic, certainly. Sergeant Eric Lambert, Royal Engineers; Mr Lambert, ineffectual teacher of physics; Eric, inadequate father and passer-on of genes, the man who had never looked me straight in the eye. [...]. There was nothing cerebral or contrived about the feeling; it was vivid, even visceral — genetic perhaps, if there is something mystic to the machinations of the genome. [...]. More than that, more than mere illusion, pathetic fallacy, whatever you wish to call it, for a moment I *was* my father. I was the man I had always longed to be. I was tall. (p. 291; emphasis original)

Through the narrator's comparison between his father and himself, the passage suggests that new technologies such as genetic engineering do not necessarily have negative consequences if their use is guided by ethical considerations. Thus, it is significant that technology in itself does not prevent Lambert from achieving happiness; it is the prejudiced society in the form of Hugo Miller that destroys Lambert's hopes of becoming 'tall'.

Consequently, *Mendel's Dwarf* seems to suggest that genetic engineering may replace nature's tyranny of chance with the tyranny of choice, the choice of the majority. In addition to Hugo Miller's crime, this view is evident in Lambert's lengthy digressions on the general history of genetics. For instance, his anecdote about August Weissmann, to whom also Daniel Hecht's *The Babel Effect* refers, illustrates a situation in which science has totally become separated from ethical concerns:

At exactly the same time as Mendel was working so brilliantly, so doggedly, with such piercing insight into the matter of inheritance, August Weissmann of the University of Freiburg im Bresgau performed an experiment of mind-boggling stupidity to disprove the theory of the inheritance of acquired characteristics. The experiment involved chopping off the tails of mice. Weissmann bred mice through five generations, over nine hundred of the wretched animals, laboriously chopping off all their tails. […]. There is something quintessentially Teutonic about Weissmann's insistence on going one further than God. He showed his talent in other directions, becoming the first honorary chairman of the Society for Racial Hygiene. (pp. 242–43)

The contrast that the passage creates between Mendel, who remains the object of the narrator's admiration throughout the novel, and Weissmann points to the possible dangers of ethically unrestricted attempts to scientific mastery. Like the character of Dr Moreau in H. G. Wells's *The Island of Dr. Moreau* (1896), Weissman completely separates scientific facts from ethical values in his desire to control nature. As such, he embodies the Faustian eugenic drive that seeks to control and perfect natural phenomena while transgressing the boundaries of ethics.

Another instance of how the novel criticizes genetic engineering through its practitioners can be seen in Lambert's portrayal of the Royal Institute for Genetics. The portrayal foregrounds not only the troubled relation between the past and the present of genetics but also the role of geneticists as present-day clergy:

On the one hand there is the old building with its ogive windows and Gothic vaulting and statues of long dead scientists in niches, like sex-maniacs skulking in the shadows; on the other hand, very much on the other hand, accessible through the kind of elevated plastic walkway that you find in airports, are the Gordon Hewison Laboratories, a cathedral of the

> new age where priests and scribes decipher and transcribe the texts, and find damnation written there just as clearly as they ever did in the medieval times. (p. 76)

The comparison between geneticists and clergy suggests that the grand narrative of religious creation now finds its extension in genetic engineering. Instead of trying to attain perfection through divinity, humankind seeks to better itself through technological application of biological knowledge; this effort, as Lambert's observation about the medium being the message indicates, is basically understood as a branch of information technology. Invested with the skill of reading the book of inheritance, the scientist becomes a surrogate god invested with the power to make what are ultimately ethical decisions.

However, it should be observed that the novel does not so much attempt to demonize science or its practitioners — although their portrayals suggest a questioning attitude to the desire to treat genetics as a means of attaining perfection — as to critically point to the ideologies and values that determine scientific praxis. For instance, the description of the director of the Royal Institute for Genetics, James Histone, implies that those values are the values of the market place. In Lambert's view, Histone embodies the notion that the results of scientific research should be commercially applicable. 'Recessives, that's the name of the game', he instructs Lambert,

> Recessives play on people's anxieties. They can spend a whole lifetime worrying whether they're carriers, and then we come along and offer them a test. [...]. Just imagine the commercial possibilities if you can design and patent a probe for something like Gaucher's disease. (p. 78)

The close link between scientific research and the values of commerce, then, actually works to limit the number of available choices — it is possible to choose but the choice has to be the same as that of the great majority. In a self-sustaining loop the values of the great majority of consumers create the values of the market place, while commercial values continue to determine the choices made by consumers.

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As can be seen above, the responses of fiction to Richard Dawkins's ideas in Daniel Hecht's *The Babel Effect* and Simon Mawer's *Mendel's Dwarf* approach the issue of identity through the explicit exposition of scientific ideas, characterization, motifs, and plot. *The Babel Effect* uses neo-Darwinist ideas as the basis of its ontology while foregrounding the notion that humankind is controlled by both internal and external factors through the protagonist's quest and the ubiquitous conspiracy motif. Moreover, the structure of Hecht's novel implies the same kind of reconciliation that Dawkins portrays in his book: at the end of the story the protagonists learn that both altruism and selfishness have a genetic basis, even though the latter remains the more fundamental impulse of the two. *Mendel's Dwarf* in turn responds to the idea that education and learning can subvert the hegemony of the selfish gene through the portrayal of its protagonist as a Frankenstein-like character and a narrative structure that juxtaposes the protagonist's story with the history of genetics, hence pointing to the various ethical questions that the attempt at scientific mastery raises.

4.3 The Not So Selfish Genes: Challenges to Neo-Darwinism in the New Biology

While the books analysed in 4.2 present the neo-Darwinian view of genes as active, intentional agents, both contemporary popular science writing and literature feature evolutionary stories that seek to offer alternative visions to the notion of the part controlling the whole. Just as the new physics challenged the theories of classical physics during the first half of the twentieth century, so the so-called new biology questions the validity of the modern evolutionary synthesis, including especially the neo-Darwinist school of thought. Like Stuart Kauffman in *At Home in the Universe*, the new biology is mainly interested in the dynamic evolution of complex systems through processes leading to emergent order. As a result, instead of regarding evolution as a fundamentally competitive affair as neo-Darwinism does, the proponents of the new biology, such as Brian Goodwin, view it as a continuous change of organisms' forms:

> There's a focus on competition in Darwinism because of the notions of progress and struggle. Now we get into theology and how it influences Darwinism, through the Calvinist view that people who have the greater accumulation of goods have proved themselves superior in the race of life. That for me is a whole lot of garbage that can be chucked. Once you get rid of it, you're into a different set of metaphors, related to creativity, novelty for its own sake, doing what comes naturally. Instead of the image of organisms struggling up peaks in a fitness landscape, doing "better than" — which is a very Calvinist work ethic — there is the image of a creative dance.[20]

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[20] Brian Goodwin, 'Biology is Just a Dance', in *The Third Culture: Beyond the Scientific Revolution*, ed. by John Brockman (see Brockman, above) <http://www.edge.org/documents/ThirdCulture/k-Ch.4.html> [accessed 11 January 2005]

Goodwin's dance metaphor stresses the idea that in the end, evolution has no other purpose than the creation of ever-changing forms and that in this process cooperation plays as important role as competition. An equally crucial implication of the notion of biology as a dance of forms is that the primary focus of the new biology is the organism, not the gene. This shows that the work of the new biologists means going 'back to where modern biology started, with Linnaeus and the classification system of different species, relationships of similarity and difference' in order to 'recover the whole organism as the real entity that's undergoing evolutionary change'.[21] Thus, the major challenge the new biology poses to neo-Darwinism concerns the reduction of the individual organism into its constituent parts: genes themselves are no longer thought as the same kind of purposeful agents as they are in neo-Darwinism, their functioning being subjected to the creativeness of the whole.

4.3.1 Evolution as a Branching Bush and Life as a Symphony of Sentient Beings

Let me begin my discussion of the visions of the new biology by considering the writing of the American palaeontologist, evolutionary biologist, and historian of science Stephen Jay Gould. As one of the most prolific and widely read popularizers of evolutionary biology, Gould's critique of neo-Darwinist approaches to evolution focuses on three points: the hierarchical theory of natural selection, the effect of internal (genetic) constraints on the

[21] Goodwin, 'Just a Dance'.

development of organisms, and the question of geological time.[22] Regarding the first point, Gould, unlike Richard Dawkins, argues that although genetic selection plays an important role in evolution, it is by no means the only powerful source in natural selection ('Life's History'). As to the second point, Gould claims that the number of possible pathways that evolution may take is limited by certain structural constraints — the so-called non-selectionist forces — that make some of the pathways more probable than others, which is in contrast to the notion of natural selection producing seemingly infinite random variability in populations ('Life's History'). Thirdly, Gould emphasizes the idea that if we study evolution at the level of geological time, it becomes possible to see that speciation may occur relatively fast as a result of catastrophes caused by earthquakes or asteroid impacts ('Life's History'). The last point is an attempt to redefine the gradualist view of biologists such as Dawkins, who argue that new species represent the cumulative end products of incremental changes over long periods of time.

My analysis of Gould's writing focuses on *Wonderful Life*, a popular science book that represents Gould's interpretation of the evolutionary implications of the Cambrian marine fossils discovered by the American palaeontologist Charles Doolittle Walcott in British Columbia's Burgess Shale in 1909. In his book Gould argues that chance has played a more decisive role in shaping the various species than evolutionary biology has been accustomed to think. He claims that although the animals of Burgess Shale were obviously well adapted to their environment, they left relatively few descendants and that those species that survived the extinction were by no means better adapted than the perished ones. Hence,

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[22] Stephen Jay Gould, 'The Pattern of Life's History', in *The Third Culture: Beyond the Scientific Revolution*, ed. by John Brockman (see Brockman, above) <http://www.edge.org/documents/ThirdCulture/i-Ch.2.html> [accessed 11 January 2005]. Further references to this chapter are given in parenthesis.

Gould draws the conclusion that evolutionary fitness does not automatically guarantee success and that chance may give a species the possibility of prevailing in the evolutionary struggle, even though it might be less well adapted than its competitors. In addition, he contextualizes his discussion of the fossils by linking it to three specific themes: the reinterpretation of the Burgess Shale discovery as an 'intense intellectual drama' of interpretation and reinterpretation, 'the awesome improbability of human evolution',[23] and the deliberate exclusion of the research on the Burgess Shale from public discussion.

A substantial part of Gould's argument in *Wonderful Life* concerns Walcott's original analysis of the fossils and his subsequent interpretation of their meaning to evolutionary theory. For Walcott, Gould observes, the fossils showed that 'life's history generally moves towards increasing complexity and diversity' (p. 111), thus drawing attention to his view that evolution should be regarded as continuous progress towards increasingly complex forms of life. For Gould, however, this constitutes a misunderstanding of the true nature of evolutionary processes, and he seeks to refute Walcott's view through his reinterpretation of the Burgess Shale discovery. After discussing the various symbolic representations of evolutionary progress in popular culture, such as the metaphors of the evolutionary ladder and cone, he proceeds to introduce an alternative to the earlier iconographies. 'Life is a copiously branching bush,' he states, 'continually pruned by the grim reaper of extinction, not a ladder of predictable progress' (p. 35). In addition to introducing Gould's own comparison, the passage uses antithesis in order to set it apart from the other metaphors. Ladders and bushes, of course, are not natural antonyms in our culture, but here they are

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[23] Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (London: Hutchinson, 1989; 1990), p. 24. Further references to this book are given in parenthesis.

forced into opposition on the basis of their metaphorical content and the linguistic form of Gould's assertion. In this way, Gould uses antithesis to replace the ladder as a widespread icon of evolution with a bush, which for him more accurately represents the unpredictable effects of contingent phenomena, such as natural disasters, on species.

Gould also criticizes the idea of evolution as progress towards increasing complexity by discussing Walcott's writing, focusing on a passage that he quotes as an example of the 'entire progressionist credo' (p. 259). After noting how Walcott equates evolution with progress — an idea diametrically opposed to Gould's argument — he cites the discoverer of the Burgess Shale as follows:

> In early times the Cephalopoda ruled, later on the Crustacea came to the fore, then probably fishes took the lead, but were speedily overpowered by the Saurians. These Land and Sea Reptiles then prevailed until Mammalia appeared upon the scene, since when it doubtless became a struggle for supremacy until Man was created. Then came the age of Invention; at first of flint and bone implements, of bows and arrows and fish-hooks; then of spears and shields, swords and guns, lucifer matches, railways, electric telegraphs. (quoted in Gould, p. 259)

The passage shows how Walcott uses incrementum in order to deliver a sense of smooth, unbroken continuum between the successive evolutionary stages. In doing so, it describes a sequence of events while at the same time indicating a certain ideology: the age of invention appears at the end of the series not only because it represents the latest stage of evolution but also because Walcott views it as the most advanced age. In contrast, Gould's metaphor of evolution as a branching bush suggests that there is no fundamental reason why man should be regarded as the pinnacle of evolution, since it is possible to envision a situation in which humankind is wiped out by a natural disaster, an event that would irrevocably alter the course of evolution on the planet.

Owing to the fact that Gould is arguing against other scientists, it is not surprising that he often uses antithesis as a means of setting his own views against theirs. For instance, in his refutation of the ladder and cone metaphors he argues that contingent occurrences such as natural catastrophes have occasionally had a more significant effect on evolution than evolutionary biology has previously thought. After the explosive diversification of life in the Cambrian period, Gould claims, ‘the later history of life proceeded by elimination, not expansion’, thus drawing attention to the role played by ‘the grim reaper of extinction’ (p. 47). The parallel structure of Gould’s formulation helps him juxtapose the two terms in order to compare them — observe how the parallel relationship is created by the use of alliteration — as well as to separate them from each other. In the same way, he sets chance against predictability through a humorous comparison between the history of politics and his favourite sport: ‘The Burgess decimation may have been true lottery, not the predictable outcome of a war between the United States and Grenada or a world series pitting the 1927 New York Yankees against the Hoboken Has-Beens’ (p. 238). This in turn foregrounds the idea that evolution is a more unpredictable affair than others are ready to admit.

Moreover, Gould takes advantage of the rhetorical power of antithesis when discussing the implications of chance for the evolution of the human species. ‘*Homo sapiens*’, he states, ‘is an entity, not a tendency’ (p. 320). The function of this antithesis is to suggest that there is nothing inevitable about human beings. On the contrary, it is possible to entertain the possibility that under different circumstances, evolution could have given birth to a markedly different kind of intelligent species. In fact, the same chapter expresses the same idea through similar syntax: ‘We are a thing, an item of history, not an embodiment of general principles’ (p. 319). Gould also uses antithesis in order to give linguistic form to the idea that it is impossible to predict which species will survive in the lottery of decimation. Quoting a well-known biblical phrase, he suggests that evolution seems to work on the basis of an eliminatory process in which 'many are called and few chosen' (p. 236). In all these examples, then, the simple structure of antithesis provides Gould with an effective means of refuting the views of rival theories. As such, antithesis is an economical way of doing refutations: its parallel structure and end focus give writers the opportunity to emphasize only those concepts that they want set apart from each other (Fahnestock, pp. 49–50).

In addition to using antithesis to create a conceptual gap between his theory and the theories of his opponents, Gould uses it to summarize some of the most important arguments of the scientists featured in his book. For instance, when saying that he agrees with Darwin that the evolution of human species and the concept of chance are inseparable, Gould summarizes Darwin's view by using an antithetical construction: 'In Darwin's scheme, we are a detail, not a purpose or an embodiment of the whole' (p. 291). In the same way, he uses a loosely formulated antithesis to summarize the traditional, 'comforting view' of the effects of mass decimation on the explosive diversification of life during the Cambrian period: 'Let a bunch of engineers tinker, and most results don't work worth a damn: the Burgess losers were destined for extinction by faulty anatomical construction. The winners were best adapted and assured of survival by their Darwinian edge' (p. 234). The traditional view thus suggests that the survivors survived because they were fitter in an evolutionary sense than the losers. In Gould's reformulation of this antithesis, however, the winners and losers are still there, but the explanation for their designation as winners and losers has undergone a radical change. 'If we face the Burgess fauna honestly,' he argues, ‘we must admit that we have no evidence whatsoever — not a shred — that losers in the great decimation were systematically inferior in adaptive design to those that survived’ (p. 236), thus refuting the implications of the antithesis expressing Walcott’s view.

Because chance affects evolution in sudden and unpredictable ways, Gould suggests, it is impossible for us to make long-term predictions about the winners and losers of evolution. In order to illustrate this point, he turns to the Bible for stylistic inspiration. ‘The sources of victory are as varied and mysterious as the four phenomena proclaimed so wonderful that we know them not (Proverbs 30:19),’ he writes, ‘“the way of an eagle in the air, the way of an serpent upon a rock, the way of a ship in the midst of the sea, and the way of a man with a maid”’ (quoted in Gould, p. 236). In this passage evolutionary variety is communicated through the anaphoric repetition of the definite article and the noun *way*, which are given different attributes. By such a simple repetitive pattern, Gould suggests that we cannot really know in advance what evolutionary pathways species will take because of the force of unpredictable natural phenomena.

After arguing that Gould seeks to refute rival theories by creating dichotomies through antithetical statements, I now want to show how he simultaneously attempts to reconfigure oppositions suggested by the antitheses in those same theories. In particular, Gould reconfigures the dichotomy between chance and determinism by opening up a conceptual middle ground between them. For this purpose, he uses a rhetorical strategy also employed by many other writers discussed in this thesis: the introduction of a new term to which the opposing concepts are subjected. For Gould, it is *contingency*, which instead of suggesting total randomness or determinism refers to the idea of ‘determined chance’ (p. 139), as Daniel Cordle puts it. Rather than making determinism seem less absolute through the foregrounding of chance, the term tries to balance the two by being ‘a thing unto itself’ (Gould, p. 51). It enables science to see better, Gould argues, that historical processes such as evolution are characterized by chance elements as much as they are characterized by non-temporal and deterministic natural laws (p. 51). Instead of constructing a new opposition or preserving an old one, then, he uses the term to suggest that determinism and randomness are not necessarily mutually exclusive terms. More than anything, they represent two extreme positions of a continuum on which contingency marks the middle ground. Hence, the insertion of the new term reconfigures rather than eliminates the dichotomy suggested by the opposition.

In addition to introducing a new term to reconfigure an existing dichotomy, Gould makes his rhetoric more persuasive by offering his readers a metaphor that exemplifies how contingency works in evolution: life’s tape. If a film containing the history of life were replayed, he claims, we would see the unfolding of radically different evolutionary pathways instead of the same sequence of events:

> The consequent differences in outcome do not imply that evolution is senseless, and without meaningful pattern; the divergent route of the replay would be just as interpretable, just as explainable *after* the fact, as the actual road. But the diversity of possible itineraries does demonstrate that eventual results cannot be predicted at the outset. Each step proceeds for a cause, but no finale can be specified at the start, and none would occur a second time in the same way, because any pathway proceeds through thousands of improbable stages. Alter any early event, ever so slightly and without apparent importance at the time, and evolution cascades into a radically different channel. (p. 51; emphasis original)

This passage, which elaborates on the implications of the life’s tape metaphor, shows how the opposition between total determinism and randomness can be reconfigured by imagining a third alternative in which the course of evolution is neither completely indeterminate nor determinate. Consequently, instead of long-term predictability, there is short-term determinism as a result of evolution's heightened sensitivity to certain initial conditions, to use the terminology of chaos theory.

* * *

While Gould has commonly been seen as Richard Dawkins's primary sparring partner in evolutionary issues, the views of Dawkinsian neo-Darwinism have also strongly been challenged by other biologists, including the American biologist Lynn Margulis. Margulis, unlike Dawkins and Gould, who represent the tradition of zoology in evolutionary biology, approaches the development of life by focusing on cells and micro-organisms. She made her main argument concerning evolution already at the end of the 1960s by proposing that evolutionary variation does not mainly follow from random mutations, as Darwinists had thought. Instead of random mutation, she argued, organs and species evolve through symbiosis, which had played a key role during the early days of organic life. Margulis based her argument on the idea that eukaryotes (cells that have a distinct nucleus) may have appeared as a result of a symbiosis of between different-sized prokaryotes (single-celled organisms that lack a distinct nucleus) (see Horgan, p. 128). She also made the claim that unlike the Darwinian theory of evolution, the concept of symbiosis could be used to explain why it is possible that species first seem to appear all of a sudden and then remain unchanged for long periods of time (see Horgan, p. 128).

In the 1970s Margulis collaborated with the English atmospheric scientist and environmentalist James Lovelock, whose famous Gaia theory focuses on the symbiotic relationship between the biota and the environment. For Lovelock, the biota is capable of self-regulating the environment as a means to survival, which by some has been interpreted that the Earth is actually a living, conscious entity. Rather than claiming that the Earth is a living organism, however, Margulis suggests that it forms a vast ecosystem consisting of smaller ecosystems.[24] Inside this ecosystem evolutionary variation is a result of symbiogenesis, a term that refers to the capability of species to create composite organisms through the mechanisms of fusion and merger.

Because of the emphasis placed on the notion of symbiosis producing novelty, Margulis's thinking challenges some of the basic assumptions of neo-Darwinism. 'Symbiosis has nothing to do with cost or benefit', she argues, 'The benefit/cost people have perverted the science with invidious economic analogies' ('Gaia'). Hence, instead of stressing the role of competition in evolutionary processes as Dawkins does, she argues that the role played by interaction between organisms in close physical contact to each other should also be recognized as an important element in the story of life ('Gaia'). This is why critics such as Steven Best and Douglas Kellner argue that in terms of its philosophical implications, Margulis's thinking — along with the ideas of other holistic-minded thinkers such as Lovelock — represents 'a powerful reaction to the static, atomistic, mechanistic outlook of modern science and the fragmentation of scientific disciplines' (*Postmodern Adventure*, pp. 121–22).

In *What is Life?*, a popular science book Margulis co-wrote with her son Dorion Sagan, the authors portray life as a phenomenon primarily based on cooperative interaction. Focusing on the role of various kinds of cells and micro-organisms in evolution, it

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[24] Lynn Margulis, 'Gaia Is a Tough Bitch', in *The Third Culture: Beyond the Scientific Revolution*, ed. by John Brockman (see Brockman, above) <http://www.edge.org/documents/ThirdCulture/n-Ch.7.html> [accessed 11 January 2005]. Further references to this chapter are given in parenthesis.

constitutes a tribute to entities that have been marginalized in many traditional representations of the development of species, and argues for the importance of a holistic view that recognizes the significance of both the microscopic and the macroscopic. Like Dawkins, then, Margulis and Sagan present a new kind of evolutionary vision but choose to foreground symbiotic cooperation instead of selfish competition.

In the first chapter of their book Margulis and Sagan attempt to define life as a phenomenon based on such interaction. They are particularly impressed by the variety of interactions occurring in different types of ecosystems. For instance, in their discussion on 'life's body',[25] the biota of the Earth, the authors express their admiration for the fact that living things utilize only a small amount of the light of the Sun. 'But what life does with that one percent is astounding', they write, 'Fabricating genes and offspring from water, solar energy and air, festive yet dangerous forms mingle and diverge, transform and pollute, slaughter and nurture, threaten and overcome' (p. 5). Although the pairs in this passage obviously represent semantic opposites, they do not necessarily suggest antithetical relationships. Used as a stylistic means of describing variety rather than exclusion, their employment corresponds to the use of opposing — or rather, seemingly opposing — terms in synoeciosis, which, unlike antithesis, aims to unite them at a conceptual level. The function of the figure in the passage is thus not to suggest that the activities are opposed to each other but rather to foreground the idea that organisms are constantly engaged in a bewildering variety of different behaviours. Using the same figure, Margulis and Sagan describe metabolism as the 'energetic maintenance of unity while components are

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[25] Lynn Margulis and Dorion Sagan, *What Is Life?* (Berkeley: University of California Press, 1995; 2000), p. 5. Further references to this book are given in parenthesis.

continuously or intermittently rearranged, destroyed and rebuilt, broken and repaired' (p. 19). They continue to use synoeciosis in the same role in the chapter 'Flesh of the Earth', which emphasizes the importance of the fungi, a traditionally undervalued group of living organisms: 'Creating and destroying, attracting and repelling, undertaking and overturning, they are part and parcel of *terra firma*' (p. 191). In the same way, the dynamic nature of living systems is described as 'a marvel of inventions for cooling and warming, moving and holding firm, stalking and evading, wooing and deceiving' (p. 214). Such pairs also help Margulis and Sagan to stylistically formulate their claim that nature is amoral rather than intentionally good or bad: '[Living beings] are no more inherently bloodthirsty, competitive, and carnivorous than they are peaceful, cooperative, and languid' (p. 236). This can be read as their way of criticizing the neo-Darwinist view of nature being predominantly 'red in tooth and claw' and at the same time making the holistic claim that 'life resembles a fractal' (p. 4), in which contrary activities are continuously repeated at different levels of organization from cells to ecosystems.

By introducing the fractal metaphor, Margulis and Sagan suggest that it is helpful to describe life in terms of a hierarchical structure. 'What is life? is surely one of the oldest questions', the authors state, 'We live. We — people, birds, flowering plants, even algae glowing in the ocean at night — differ from steel, rocks, inanimate matter' (p. 2). As the conceptual basis of their definition of life, Margulis and Sagan thus use a series of items — basically an incrementum — that proceeds from the biologically most complex item, people, towards the least complex one, the non-flowering photosynthetic plants, or algae, to separate the animate from the inanimate in an antithetical fashion. Although the items on this simple list could easily have been replaced by other similar items to achieve the same stylistic effect, the series is nevertheless to a certain extent argumentative. Its argumentativeness stems from the fact that it seeks to conceptually extend the category of animate matter through the inclusion of algae, whose importance to life on the Earth has been undermined by anthropocentrism, one of the major targets of the authors' criticism.

The authors' exposition of the fractal metaphor is also articulated by an incremental series that proceeds from the bottom to the top. Viewed as a hierarchical structure consisting of various levels of complexity, life can be understood as a series of nested constituents that are iterated fractal-like throughout an entire spectrum of levels:

> The 'fractals' of life are cells, arrangements of cells, many-celled organisms, communities of organisms, and ecosystems of communities. Repeated millions of times over thousands of millions of years, the processes of life have led to the wonderful, three-dimensional patterns seen in organisms, hives, cities, and planetary life as a whole. (p. 4)

Through the inclusion of two series, this passage suggests that a certain kind of structural isomorphism characterizes life, regardless of the level of complexity at which it occurs. As such, the series rhetorically support Margulis and Sagan's use of the concept of holarchy, through which they aim to challenge the traditional notion of the 'great chain of being' (p. 9) in evolutionary biology. In contrast to the anthropocentrism suggested by the great chain of being, which is basically an incrementum ending at the most 'important' item on the list, humankind, the idea of holarchy foregrounds the interdependent coexistence of wholes and their constituents. Although the series in the quotation above may suggest that life is indeed a hierarchically structured phenomenon, the implied analogy between organisms and man-made structures suggests that what may appear as a strict, evaluative hierarchy is not a hierarchy at all, but rather a network of interdependent, coexistent parts that cannot be described in terms of the low-high, unimportant-important dichotomy that characterizes the idea of the great chain of being. Because the different levels of the organization of matter share the same fractal structure, the relationship between the first and the last items in the series changes. Instead of a conceptual gap between 'low' and 'high' organisms, there is now a continuum of similar structures that unites the opposite poles, suggesting that the two have more in common than evolutionary biology has previously thought.

The idea that humankind cannot be considered as an entity separate from the other life-forms of the holarchy is also foregrounded by the characteristically lyrical language of the book. Margulis and Sagan frequently employ alliteration, as well as the repetition of key words, phrases, and certain kinds of syntactical structures. For instance, the authors describe the relationship between humans and other types of life in the epilogue as follows:

> Knowledge about the varieties of life on Earth — life which, from pond scum to tigress, is connected to us through time and space — serves to inspire. That excess is natural but dangerous we learn from the photosynthetic ancestors of plants. That movement and sensation are thrilling we experience as animals. That water means life and its lack spells tragedy we garner from fungi. That genes are pooled we learn from bacteria. (p. 246)

In this passage the arrangement of the four sentences beginning with *That* is clearly anaphoric. The repetition of a certain type of sentence structure has a distinctive amplificatory effect that serves to foreground the idea that because life forms an interdependent continuum, humankind should not hubristically think of itself as qualitatively better than life-forms positioned at other points on the continuum. Rather, Margulis and Sagan argue, our knowledge of nature should teach us humility, since that knowledge requires constant interaction with the different levels of the ecosystem. As the passage therefore suggests, humans appear as students learning from other forms of life rather than vice versa.

Similar repetition also takes place in the short summaries that conclude the book's each main chapter. For instance, Margulis and Sagan summarize the main ideas presented in their discussion about the roles played by certain plants in transforming sunlight into energy as follows: 'Life is the transmutation of sunlight. It is the energy and matter of the sun become green fire of photosynthesizing beings. It is the natural seductiveness of flowers. It is the warmth of the tiger stalking in the jungle in the dead of the night' (p. 212). Through the passage's anaphoric structure, the authors that suggest life is essentially a multifaceted phenomenon that cannot be given a single definition. Instead of actually answering what life is, Margulis and Sagan offer their readers different kinds of images that reflect its myriad aspects. Just as life transgresses rigid boundaries, they suggest, so it at the same time transgresses our limited ways of depicting and understanding it.

In addition to anaphora, Margulis and Sagan's definition of life often features the use of ploche. For instance, linking forward to the argument of the last chapter of the book, they state that 'we pursue the unorthodox but commonsensical idea that life — not just human life but all life — is free to act and has played an unexpectedly large part in its own evolution' (p. 4). The syntactically free repetition of the noun *life* in this sentence epitomizes a fundamental part of the authors' argument in the whole book: life is characteristic not only of certain beings but also of things traditionally considered inert or dead, such as minerals. In other words, this is how the message that life is everywhere is forced into the consciousness of readers. Such a rhetorical strategy also helps foreground the idea that humankind is not qualitatively different from other forms of life in the sense that it too is a material product of autopoiesis, the chemical process all organic beings use for self-maintenance. Indeed, the word is repeatedly positioned at the beginning of sentences in the short summarizing paragraphs headed ‘So, What is Life?’ that end each chapter (see Margulis and Sagan pp. 31–32, p. 55, p. 86, pp. 110–11, p. 144, p. 170, p. 191, and pp. 211–12). Another good example of this is the last paragraph of the epilogue:

> *Homo sapiens* tends to dissipate heat and accelerate organization. Like all other life forms, our kind cannot continue to expand limitlessly. Nor can we continue to destroy the other beings upon whom we ultimately depend. We must begin really to listen to the rest of the life. As just one melody in the living opera we are repetitious and persistent. We may think ourselves creative and original but in those talents we are not alone. Admit it or not, we are only a single theme of the orchestrated life-form. With its glorious nonhuman past and its uncertain and provocative future, this life, our life, is embedded now, as it has always been, in the rest of Earth’s sentient symphony. Now, as before, life is empowered by the sun. It is a phenomenon not only molecular but astronomic. Life is open to the universe and to itself. In the tradition of Charles Darwin, Samuel Butler, Vladimir Vernadsky, and Erwin Schrödinger, we can ask with curiosity but can answer only tentatively and with humility the question what life is, hoping, with you, that the search continues. (p. 246)

Although the function of ploche in this passage — especially the repetition of the words *life* and *we* — is clearly stylistic, since it provides a means of increasing the cohesion of the paragraph, its use can be nevertheless read as an argumentative way of buttressing the claim that life — as organisms’ consciousness of their surroundings — is an all-pervasive phenomenon that connects the microscopic to the macroscopic in order to create ‘the sentient symphony’ (p. 243) of life. The repetition of *we* in turn invokes the sense of communality, and implies that the recognition of these issues is of vital importance to all humankind, hence contributing to the presentation of the book’s ethos.

Moreover, it should be noted that in addition to the figures discussed above, metaphor plays an important role in communicating the authors’ argument to their readers. Margulis and Sagan complete their definition of life by introducing an extended metaphor through which they foreground the dynamic nature of life’s variety in musical terms:

> The continuous metamorphosis of the planet is the cumulative result of its multifarious beings. Humankind does not conduct the sentient symphony: with or without us, life will go on. But behind the disconcerting tumult of the present movement one can hear, like medieval troubadours climbing a distant hill, a new pastorale [*sic*]. The melody promises a second nature of technology and life, together spreading Earth's multispecies propagules [those parts of organisms that can be detached in order to grow new organisms] to other planets and the stars beyond. (p. 243)

Through the metaphor of life as a sentient symphony, Margulis and Sagan aim to capture the essence of their non-anthropocentric view. Instead of humankind leading the symphony of life as the conductor of the orchestra of life-forms, there is a global multitude of musicians who all contribute to the music. The metaphor also suggests that in terms of the relationship between the whole and its constituent parts, it is the whole that matters in the end: the symphony will continue even though some members of the orchestra should stop playing. It is worthwhile to notice that in this important sense the metaphor functions as an alternative to Dawkins's metaphor of the selfish gene. Although Dawkins uses his metaphor to describe the relationship between the organism and its genes, we might, along with Mary Midgley, argue that his way of using it is indicative of the widespread — and potentially harmful — tendency of needlessly atomizing wholes in contemporary science. Discussing the way in which parts of the globe such as the Antarctic have been granted a special status, Midgley notes that

> there is, indeed, something unreal about the whole way of thinking which speaks of these places as though they were distinct individual 'wildernesses', units which are applying separately for admission to our value-spectrum. Though we divide them for our thought, they function as parts of the whole. At present, indeed, the Arctic and the Antarctic are letting us know this because their ice, melted by global warming, is affecting the entire state of the oceans.[26]

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[26] *Science and Poetry*, p. 187.

In contrast to the selfish gene metaphor, then, the idea of life as a sentient symphony places primacy on the whole, proposing that a truly ethically aware way of thinking needs to pay attention to factors outside the immediate concerns of the individual self. Furthermore, unlike the great chain of being metaphor, it suggests that instead of representing the culmination of evolutionary process on the Earth, humankind is in the end a more or less dispensable part of the planetary whole.

In addition to describing the variety of life, a major part of Margulis and Sagan's argument in *What is Life?* concerns the reformulation of dualisms that the authors see as incompatible with the notion of life as a sentient symphony — above we already saw how their portrayal of the variety of life partly aims at this end. The authors hold that much of the history of Western thinking is characterized by 'metaphysical dualism' (p. 48) that tends to operate in terms of simplistic dichotomies, such as human/non-human, life/non-life, mind/body, and spirit/matter. The major problem with such oppositions, Margulis and Sagan claim, is that they cannot capture the complexity of reality when nature is examined closely. What is more, in many cases the opposition appears to make a statement about the value of the concepts in regard to each other. For instance, in the four dichotomies given above it is the first term that has usually enjoyed a higher status than the second one.

In order to reconfigure the first two dichotomies, human/non-human and life/non-life, Margulis and Sagan discuss the distinction between natural selection in the relations of nonhuman forms of life and their environment, and artificial selection (the effects of breeding, for instance, on animals and plants) in Darwin's evolutionary theory. Rather than accepting this dichotomy, the authors seek to reconfigure it because for them real natural selection is ‘more “artificial,” and far less mechanical’ (p. 220) than Darwin’s presentation of it. This reconfiguration is based on the claim that very simple organisms, such as prokaryotes, are able to make choices and learn. In other words, they are capable of activities usually associated with ‘higher’ and more complex organisms. As support for their claim Margulis and Sagan quote the biochemist Daniel Koshland:

> ‘Choice,’ ‘discrimination,’ ‘memory,’ ‘learning,’ ‘instinct,’ ‘judgment,’ and ‘adaptation’ are words we normally identify with higher neural processes. Yet, in a sense, a bacterium can be said to have these properties. […]. For example, learning in higher species involves long-term events and complex interactions, but certainly induced enzyme formation must be considered as one of the more likely molecular devices for fixing some neuronal connections and eliminating others. The difference between instinct and learning then becomes a matter of time scale, not of principle. (quoted in Margulis and Sagan, p. 219)

The antithesis in the last sentence suggests that there is no fundamental reason why ‘lower’ organisms such as prokaryotes could not be considered capable of learning. Margulis and Sagan illustrate this point through simple examples with antithetical structures: while chemotactic bacteria ‘swim toward sugar and away form acid’, ‘microbes sense and avoid heat, move toward or away from light’ (p. 219). In this way, the authors use simple antithetical pairs to support their argument for viewing lower organisms as sentient beings. In terms of the dichotomy apparent in Darwin’s distinction between natural and artificial selection, such pairs help Margulis and Sagan reconfigure the original opposition. Because self-awareness characterizes the activities of living beings at a variety of levels, the distinction becomes less strict: like human breeders, simple organisms are capable of making advantageous choices affecting their immediate surroundings, including the lives of higher-level organisms.

Moreover, this argument reconfigures not only the opposition between natural and artificial selection but also that between human and non-human forms of life. If the latter are able to make choices not only in an analogous or a metaphorical sense, Margulis and Sagan argue, they can be said to interact with their surroundings as much as humans do. Rather than postulating a qualitative difference between the two categories, then, the authors suggest that there is a continuum of consciousness that connects the categories to each other. The only definite difference they see between them is that humankind is the only species with the ability to self-deceive (p. 221). Once again, Margulis and Sagan summarize the implications of their argument through antithesis: 'The gulf between us and other organic beings is a matter of degree, not of kind' (p. 222). Hence, they thoroughly reconfigure the original Darwinian dichotomy by replacing the opposition with a continuum. In their view, life is not just about mechanistic adaptation; it is also about making choices at a multitude of levels — or, as the authors antithetically put it, there is 'the life we are given and the life we make' (p. 222).

The authors also seek to question the dichotomy between forms of life traditionally regarded either low or high by using argumentative series. Arguing against the anthropocentric view of evolution evident in the great chain of being, they suggest that 'the notion of progress from "low" bacterium to "high" human is a delusion of grandeur' (p. 152), and begin their redefinition of this opposition by asking, 'What has a person in common with a worm, a starfish, and a million kinds of beetle?' (p. 152). Margulis and Sagan then proceed to subject the opposites to an inclusive term: 'Animals, whether in the urban dark of a barroom or by a moonlit equatorial reef, all share the same life cycle' (p.

152). The authors describe the inclusive term, *life cycle*, as a series of events included in a process shared by low as well as high animals:

Fusion of the two different-sized cells, egg and sperm, begins the process of animality. The sperm and egg merge into a single fertilized egg that divides by mitosis to form the blastula. As cell division continues, the fertile egg becomes the embryo — often a hollow ball of cells. […]. Just as the embryo distinguishes the animal and plant kingdoms, so the blastula embryo distinguishes the animal from the plant.

[…].

The blastula embryo is the animal universal in all thirty-eight or so phyla. In the usual course of animal development the cells of the blastula continue to divide, move, and die. They form the next stage, the gastrula, which makes a new mouth at the front end of a digestive tube. The mouth is succeeded by a swelling, a stomach, and an anus in this unfolding process, called, logically enough, 'gastrulation.' (Margulis and Sagan, pp. 152-53)

By explicitly describing the various important stages in the shared life cycle of low and high animals in an incremental fashion, Margulis and Sagan are able to make their argument about the falsity of the human-animal dichotomy more convincing. Most importantly, their view lacks the evaluative element that characterizes the anthropocentric view: at a very basic level, the authors argue, humans and animals have more in common than the ladder metaphor allows us to believe. In other words, then, there is no fundamental, qualitative difference between the two in regard to the whole of life.

Another example of series giving form to Margulis and Sagan's idea of life as a whole constituted by interconnected parts is provided by the authors' illustration of how bacteria function as recyclers of chemical compounds, such as nitrogen, sulphur, and carbon:

The organically bound nitrogen in proteins and amino acids takes many routes. Some is degraded to ammonia (NH_3) by a diversity of bacteria. Ammonia is oxidized to nitrite (NO_2) or nitrate (NO_3) by still other bacterial specialists. Nitrite and nitrate, in turn, fertilize the water, letting cyanobacteria and others grow. Nitrite and nitrate may be 'breathed' by some bacteria which vent nitrous oxide ('laughing gas') and nitrogen (N_2) into the air.

> Nitrogen gas in the atmosphere must then be fixed again. The complex cycle never ceases. (p. 107)

Although the series in this passage does not constitute a pure gradatio — the repeated words, *ammonia*, *nitrite*, *nitrate*, and *nitrogen*, do not immediately follow each other — it nevertheless gives a sense of a series whose items overlap. Because it includes the intermediate points between the beginning (ammonia) and the end point (nitrogen gas), this syntactically loose gradatio seeks to bring the opposite points together by describing readers how the items between them establish a causally connected series. The repetition of the key terms enables Margulis and Sagan to foreground the idea that such recycling takes place between the interconnected parts of the whole process. Again, in terms of the relation of Margulis and Sagan's argument to neo-Darwinism, we may note how the image of recycling foregrounds the role of the parts actively seeking to benefit not only themselves but also the whole of ecosystem.

Interestingly, before they present this particular example, Margulis and Sagan discuss how humankind is inextricably linked to the process of recycling, as humans become 'food' for bacteria when they die. In order to illustrate how things are interrelated in a cyclical fashion, they quote the sixteenth-century Italian Renaissance philosopher Giordano Bruno, who in his description of the transformation of matter employs quite an exemplary gradatio that he combines with a descending incremental series:

> That which was seed will get green herb, and herb will turn into ear and ear into bread. Bread will turn into nutrient liquid, which produces blood, from blood semen, embryo, men, corpse, Earth, rock, and mineral and thus matter will change its form ever and ever and is capable of taking any natural form. (quoted in Margulis and Sagan, p. 91)

Note how Bruno does not place the word *corpse* at the end of the series but rather close to its middle, thus giving it an intermediate position. In the context of Margulis and Sagan's discussion of the life-death dichotomy, its placement indicates that from the viewpoint of recycling, life and death are not antithetically opposed to each other at the bacterial level. Instead, there is a continuum of existence — in the form of the cycle of life — throughout the various organizational levels of matter. Bruno's formulation, then, persuasively supports Margulis and Sagan's claim that unlike the mammalian body, the bacterial body 'has no limits' (p. 97), as bacteria can avoid thermodynamic equilibrium by bringing 'dead' matter back to life through recycling.

Bruno's series also buttresses Margulis and Sagan's critique against anthropocentrism. That the word *men* is placed in the middle of the series in the second sentence indicates that humankind should be considered just another part in the great cycle of life. By making humankind an intermediate point in the cycle of life rather than its end, the series — like the metaphor of sentient symphony — displaces humankind from the top of the evolutionary ladder. It could be thus argued that just as the process of transformation produces food to benefit humans, so humans can be seen as metaphorical food that benefits other forms of life, such as bacteria. In this kind of holarchical model, then, none of the parts in the whole of the cycle are given primary importance, just as the relationship between the whole and its parts cannot be defined solely in terms of primacy: both the whole and the parts are equally real, although Margulis and Sagan suggest that the whole is able to survive without all the parts.

An additional case of the authors' use of such series is found in their description of yet another example of the unsung heroes in the story of evolution: the single-celled algae and phytoplankton that are collectively known as coccolithophores. Margulis and Sagan illustrate their argument about the importance of a particular representative of this group of marine protoctists (the eukaryotic, nucleated micro-organisms, and their immediate multicellular descendants) for the Earth's atmosphere as follows:

> Because salt accumulates in its cell and can destroy it, a coccolithophorid must make complex sulfur compounds that balance internal ion concentrations. These sulfur compounds are unstable; they break down to form dimethyl sulfide, a waste gas wafted into the air. Once released, dimethyl sulfide gas reacts with oxygen to produce tiny aerosol particles of sulfate. These particles seem to be involved in the formation of cloud cover by serving as nuclei for the condensation of water vapor. Since the cloud cover radiates back to space and leads to cooler temperatures, a bloom of coccolithophorids such as *Emiliania huxleyi* may act as a global air conditioner. (p. 142)

Although the repetition of the terms *sulfur compounds* and *dimethyl sulfide* does not fill the requirements of a strict gradatio, it nevertheless suggests reasoning based on an overlapping series. Similarly, the juxtaposition of *tiny aerosol particles of sulfate* and *These particles* loosely corresponds to the structure of gradatio proper, although the latter term does not precisely repeat the grammatical form of the former. Hence, despite its loose construction, the passage delivers exactly the same rhetorical effect as a similar passage built on textbook repetition would: it supports the authors' argument by emphasizing the interdependence of the microscopic single-celled beings and all the other life forms that constitute the biosphere.

Just as they seek to reconfigure the dichotomy between low and high animals, so Margulis and Sagan aim to undo the one between matter and mind. In the second chapter they discuss the history of 'metaphysical dualism' (p. 48), which they see as a characteristic feature of Western culture, and argue that as a consequence of its pervasive dualism human thought tends to operate in terms of basic conceptual oppositions, such as mind/body, spirit/matter, and life/non-life (p. 48). For Margulis and Sagan, however, such oppositions are unwarranted from the viewpoint of life as a dynamic, holistic process:

> From a thermodynamic, autopoietic perspective, the basest act of reproduction and the most elegant aesthetic appreciation derive from a common source and ultimately serve the same purpose: to preserve vivified matter in the face of adversity and a universal tendency toward disorder. (p. 43)

Using these two concepts as illustrative examples, the authors proceed to challenge the validity of rigid dichotomies by subjecting the terms to a new, superior term: autopoiesis, which refers to life's capacity for self-sustenance. Hence, they suggest that instead of constituting absolute or unmediated opposites, certain fundamental dichotomies are not opposed to each other in the way our language and thinking would have us to believe. The new, inclusive term, then, seeks to undo the qualitative difference between the opposing terms by claiming that as products of autopoietic processes, body and mind, the low and the high, are complementary rather than opposite phenomena.

Accordingly, drawing on the thinking of the nineteenth-century English novelist Samuel Butler, the authors suggest that since the physical and the mental are by no means concepts opposed to each other, they should be placed on the same kind of continuum as human and non-human life. As in the previous example, Margulis and Sagan undo the opposition by subjecting the two concepts to a third term: 'The mind and the body are not separate but part of the unified process of life' (p. 232). Life is in turn unified because it is, in some sense, a conscious phenomenon at all levels, as the passage concerning the learning abilities of prokaryotes suggests. After noting that life 'is capable of thinking' (p. 232), the authors employ an ascending incremental series in order to show how the high of thought blends with the low of certain physical processes in the brain during the act of reading:

In comprehending these sentences, certain ink squiggles trigger associations, the electrochemical connections of the brain cells. Glucose is chemically altered by reaction of its components with oxygen, and its breakdown products, water and carbon dioxide, enter tiny blood vessels. Sodium and calcium ions, pumped out, traffic across a neuron's membranes. As you remember, nerve cells bolster their connections, new cell adhesion proteins form, and heat dissipates. Thought, like life, is matter and energy in flux; the body is its 'other side.' Thinking and being are the same thing. (pp. 232–33)

Just as the series quoted in the examples above, so this one establishes a sense of continuity by describing the various interconnected stages of a cycle: the writing on the page (the physical) affects the reader's thoughts (the mental) that in turn affect the processes in the brain (the physical) — that is, the passage shows that there is a causal loop between mind and body. In this way, then, it makes rhetorically more persuasive the claim that on the whole, body and mind are interconnected rather than separate phenomena. The argument receives additional support from the analogy between thought and life at the end of the passage. Everything is thought not in an idealistic but in an emergent, autopoietic sense: thinking emerges from certain chemical processes in organisms (Margulis and Sagan, p. 233). Hence, the authors suggest that there is no qualitative difference between the two concepts, as the relationship between them is based on complementarity rather than opposition.

*   *   *

The above analyses of Stephen Jay Gould's *Wonderful Life* and Dorion Sagan and Lynn Margulis's *What is Life?* highlight the authors' employment of figurative language in their arguments against the neo-Darwinist account of evolution. A marked feature of Gould's rhetoric is his use of antithesis, with which Gould refutes the views of other theorists in order to argue that chance factors have played a more significant role in evolution than previously thought. At the same time he reconfigures the opposition between chance and determinism by introducing contingency as an all-inclusive third term, balancing the scales between the two. In his argument Gould also employs metaphor: both the branching bush of evolution and life's tape suggest that evolution is an unpredictable affair that does not necessarily lead to increased complexity and diversity.

The distinctively near-poetic language of Dorion Sagan and Lynn Margulis in turn displays a more wide range of rhetorical figures. For instance, the authors use synoeciosis as a means of foregrounding the diversity of organisms' behaviour while employing different types of repetition in order to stylistically formulate their argument that life transgresses the boundaries drawn by humankind. Also characteristic of their rhetoric is the employment of incrementum and gradatio, which they use to illustrate the notion that the totality of life resembles a fractal with many interconnected parts. Moreover, Sagan and Margulis reconfigure various dichotomies through antithesis and umbrella terms. Finally, the metaphor of sentient symphony presents an alternative image for Richard Dawkins's selfish gene, foregrounding cooperation between species rather than the selfishness of individual actors.

4.3.2 Evolution as Contingency and Cooperation

Let us now turn to look at the responses of contemporary literature to the evolutionary ideas of the new biology. I begin my analysis by discussing the British hard science fiction author Stephen Baxter's *Evolution*, a novel that seeks to address questions similar to the ones studied by Stephen Jay Gould in *Wonderful Life*, especially the role played by chance and contingency in the development of the species and their relevance to the status of humankind. Like Gould, Baxter suggests that it is impossible to determine beforehand the direction of evolution and that instead of constituting the pinnacle of life's development on the Earth, humankind is just another species on its way of becoming extinct in the branching bush of evolution.

Evolution portrays the whole story of the species from its hypothetical beginning to its similarly hypothetical end. The first part of the novel focuses on crucial events such as the mass destruction of dinosaurs and the rise of early primate societies. The second part in turn traces the evolution of language, religion, and self-consciousness; the invention of farming; the building of cities; and the last days of the Roman Empire. Finally, the third part speculates on the destiny of humankind: after the destruction of present-day humans, the story follows the lives of their remote descendants until their extinction on a planet that has become inhospitable for life.

Baxter's story proceeds from the past towards the future without establishing a strictly chronological plot, as the prologue, the interlude, the epilogue, and the sixteenth chapter establish a frame story that follows the arrival of the palaeontologist Joan Useb and her daughter to a conference held in Darwin on environmental issues and their eventual settling on the Galapagos Islands after a natural disaster in 2031. Through the description of the interdisciplinary conference, the novel foregrounds the beginning of the twenty-first century as a crucial moment in the evolution of humankind: the external appearance of the species is commercially modified through techniques of genetic engineering, and recurring natural catastrophes pose a threat to human existence on a global scale. About halfway through the story a massive natural catastrophe wipes out most humans, but evolution continues to produce novel forms of life that adapt to the changed circumstances.

In terms of the notion of evolution equalling progress — the suggestion made by the ladder and cone metaphors of evolution — the fact that the story of human evolution in the novel continues far beyond the near future is significant because it raises the question whether such metaphors really constitute an accurate means of portraying evolution. Rather than suggesting that humankind constitutes the pinnacle of evolution, Baxter seems to agree with Gould's view of *Homo sapiens* as 'a wildly improbable evolutionary event' (*Wonderful Life*, p. 291), an accident rather than something predestined to survive. As I observed in 4.3.1, one of Gould's fundamental claims about the nature of evolution is that the course of the process is shaped by various, historically determined local factors, whose effects are very difficult to predict. This, however, does not mean that evolution is a genuinely random phenomenon. Instead of claiming that the current moment is causally unrelated to the past, it would be more accurate to say that it is difficult — if not impossible — to predict the future on the basis of our knowledge of the past.

With its focus on the catastrophic nature of natural history, then, it is not surprising that in *Evolution* we find several portrayals of events that foreground the effect of chance on the development of species. For instance, the mass extinction of dinosaurs as a result of a comet impact, portrayed at length in the third chapter, leads to the birth of new species that are better equipped to survive in the changed conditions. Before the comet hits the Yucatan peninsula, the distant ancestors of humankind such as the rodent-like Purga, whose genetic heritage flows through the characters living in different historical periods, lead marginal lives in a world dominated by dinosaurs. Purga, however, survives the disaster because of two characteristics: her small size — a definite disadvantage in the pre-comet world from the viewpoint of natural selection — and her hot-blooded metabolism, which constitutes 'an *unplanned* advantage'[27] in the post-comet life. In comparison, dinosaurs are decimated because of traits that had made them so successful in earlier times, such as their large size. Hence, the novel emphasizes the difficulty of predicting the eventual effects of chance events on evolution, as the existence of certain traits at a given moment does not automatically guarantee their usefulness in a radically altered future. Given this state of affairs, unpredictable natural disasters seem to be historical anomalies only from the viewpoint of human observers, not of evolution itself:

> Events that came less frequently than [a century or so] — such as asteroid impacts — were placed in human minds, in the category, not of *rare*, but *never*. But the impacts happened even so, and to a creature with a lifespan of, say, ten million years, would not have seemed so improbable at all. (p. 166; emphases original)

Because of the wide temporal scope of the novel — from about 145 million years before the beginning of Common Era to roughly the year 500 000 000 in a distant future — we are allowed to adopt the viewpoint of such a hypothetical creature. In this way, unpredictable events are established alongside natural selection as one of the primary factors shaping the future of the various species.

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[27] Stephen Baxter, *Evolution* (London: Gollancz, 2002), p. 29; emphasis added. Further references to this book are given in parenthesis.

The catastrophe motif — all the historical periods depicted in the novel end with some kind of disaster, be it either natural or caused by human action — not only emphasizes the effect of chance on evolution but also questions the notion of evolution as a gradually progressive phenomenon. While the ladder (upward movement) and cone (increasing diversity) metaphors suggest that *Homo sapiens* develops gradually through successive stages of physical and intellectual progress, Baxter's novel responds to their implications by depicting the hypothetical effects of mass extinction on present-day humankind. Rather than representing the culmination of a linear progress, the human species is just another branch on its way of becoming extinct, which is suggested by the fact that the last representatives of humankind lack some of the fundamental markers of advanced species. For instance, the last representative of the genetic continuum in the novel, the monkey-like Ultimate, is not conscious of its own existence, as it lives in a symbiotic relationship with 'The Tree' (p. 551), and survives by foraging small animals, just like its earliest ancestor, Purga, did. Implicit in humankind's return to the trees is the suggestion that evolution is an aimless cyclical process rather than a linear process with a definite aim. From the viewpoint of the notion of evolution as progress, then, the novel's so-called post-people are obviously an evolutionary throwback resembling the earliest ancestors of humankind.

The notion of evolution as a progressive phenomenon is also undermined by the fact that the brains of the post-people have become atrophied in order to adapt to the environment: instead of human forebrain, they merely have 'a spongy bone' (p. 551), which regulates the temperature of their heads. Well-adapted to their environment, the post-people have no need for the large, complex brain that has traditionally been regarded as the indicator of evolutionary progress, as in their burnt-out world a large brain would reduce rather than increase the chance of survival. In other words, the superior intelligence of the present form of humankind is nothing more than an evolutionary strategy, which according to the novel is a trait not necessarily advantageous in terms of the survival of the species. In this way, then, Baxter's novel aligns itself with the Gouldian view of progress and time by questioning those narratives of evolution in which the human brain symbolizes a fundamental discontinuity — and progress — in the development of the species.[28] More than anything, it suggests that the various forms of life do not progress limitlessly towards increased complexity and diversity.

If evolution has no particular direction, does it follow that it has no purpose? The above examples show that the novel's depiction of evolution does not represent it as progress: instead of purposefully driving humankind towards increasingly advanced forms, evolution is sensitive to changes brought about by external factors, such as natural disasters. As we have seen, such changes are not meaningful in terms of progress; they just cause species to embark on unpredictable evolutionary pathways. Especially the diction the narrator uses to describe the mechanisms of evolution suggests that there is no higher purpose to why species keep mutating. For instance, while 'the blind scalpels of evolution' (p. 79) give shape to the form of species, there appears to be 'no sense of improvement, of purpose' (p. 108) in the process. Thus, the narrator's commentary foregrounds the idea that there is no teleological drive involved in such mechanisms and that in the place of a watchmaker — the eighteenth-century English theologian William Paley's metaphor for an intelligent creator — we find purposeless nature.

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[28] A similar idea is employed in Kurt Vonnegut's *Galapagos* (1985), which, like *Wonderful Life*, questions the notion of evolution as progress (see Cordle, p. 139).

In this way, blind chance is given the same constructive role that was previously assigned to notions such as a divine designer. This is especially evident in the novel's portrayal of the time before the emergence of the present-day humankind. During the early days the destiny of species is totally dependent on external factors: 'Animals rode across oceans on impromptu rafts,' the narrator notes, 'oceanic odysseys undertaken not by choice or design, but by the vicissitudes of chance' (pp. 165–66). Similarly, had Purga not survived, the present form of humankind would never have emerged: 'Others of her kind would breed, of course; other lines would go on into far distant futurity, to grow, to evolve — but not Purga's line, not *her* genes' (p. 17; emphasis original). Recalling the implications of Gould's metaphors of lottery of decimation and the tape of life, *Evolution* thus establishes the status of humankind as a unique species that would not emerge in the same form were the whole process to begin from scratch. Indeed, this view is explicitly stated at the end of the novel, where evolution begins all over again on another planet, yet this time having 'nothing to do with mankind' (p. 575).

Instead of advancement and progress, then, it is survival that seems to be the ultimate source of meaning in the novel. Significantly, Baxter portrays the first and last representatives of the human species as nothing more than survival machines whose actions are motivated by the passing on of their genes. While the early ancestors are driven by the robotic 'logic of survival' (p. 82) to breed as fast as possible in order to survive the attacks of predators, the descendants of humankind are similarly unaware of their motives, living only for the present moment and being incapable of consciously controlling their destinies. Although these creatures seem to have no functions apart from reproductive activities and adaptation to local conditions, they are still winners in the lottery of life by surviving long enough to reproduce.

In this sense, then, evolution appears as an autonomous, repetitive process, whose highest priority is the establishing of genetic continuity. Describing the breeding strategies of dinosaurs, the narrator laconically notes that 'most of the chicks would die — but that didn't matter. It was enough that some would survive' (p. 13). After the Rabaul catastrophe the priority remains exactly the same, as suggested by the portrayal of the mole-folk, another species of human descendants living in colonies consisting mostly of sterile females whose task is to take care of the progeny of its queens. It is evident that the mole-folk are driven by the genetic imperative as much as dinosaurs once were:

> For the genes it made sense, of course. Otherwise it would not have happened. […]. By ensuring the preservation of the colony, you could ensure that your genetic legacy was transmitted to the future, even if not directly through your own offspring. In fact, if you were sterile, that was the *only* way you could pass on your genes. (p. 540; emphasis original)

Using a tone that is as neutral as the process it describes is purposeless, the narrator suggests that from the viewpoint of genes, it is crucial that the needs of the community surpass those of its individual members. In fact, this kind of genetic imperative is so strong that it often leads to self-destructive behaviour. For instance, in their search for food the chthonic mole-folk employ strategies that are costly in terms of individual lives: they emerge in vast numbers from their tunnels on the ground only to be slaughtered by predators. Because of their ability to breed fast, however, they are able to reach their ultimate aim: 'The genes would go on: that was all that mattered' (p. 544). As the critic

Adam Roberts notes, in comparison to Dawkins's selfish genes, 'Baxter's genes just *are*, and they are in the process of keeping themselves going'.[29]

Indeed, *Evolution* makes the issue of genetic survival so crucial that it is explored from the viewpoint of not only organic beings but also machines. By the time of the Darwin conference, a robot has been sent to excavate iron from the Martian soil and to carry out an experiment in self-replication. However, the same natural catastrophe that decimates most of humankind eventually also affects the destiny of artificial life. In absence of human supervision, the robots launch an evolutionary process on their own: through trial and error they develop 'a radically better design' (p. 496), make copies of these designs, fight against each other over resources, and finally destroy the planet by overpopulating it. In other words, their evolutionary process is more or less the same as the one humankind has experienced. In this way, the genetic imperative to contribute to the 'river of genes' (pp. 10, 86) is shown to be an overriding concern for both organic and inorganic beings — just as that of the ancestors and descendants of present-day humankind, the sole purpose of the robots is 'to replicate' (p. 495).

In terms of our discussion of the role of contingency in evolution, the portrayal of the self-replicating robots also underlines the notion that humankind should not be considered an exceptional form of life. This is evident in the fact that during their long evolution the robots acquire a trait that has previously belonged only to their designers: consciousness. In the penultimate chapter of the novel one of the highly advanced robot replicators lands on the Earth to seek information about its lost origins. 'The sphere was a living thing,' the

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[29] Adam Roberts, 'Baxter's Evolution: Fiction Evolves', *The Alien Online*, January 2003, <http://www.thealienonline.net/> [accessed 31 January 2004] (emphasis original)

narrator notes, ‘and yet it was not. It was not an artefact, and yet it was not that either. The sphere had no name for itself, or for its kind. Yet it was conscious’ (p. 569). Thus, by attributing an important human characteristic to a machine, Baxter’s novel questions the status of consciousness as a trait that sets humankind apart from other forms of life.

Owing to the underlying premise that humankind constitutes just another stage of evolution rather than its pinnacle, it is not surprising that at the end of *Evolution* the natural and the artificial largely merge. Just as organic beings are nothing more than survival machines, so machines now display features characteristic of organic beings. The sphere is an apt symbol for this kind of union because, like humankind, it represents an evolutionary accident. ‘It was somehow appropriate’, the narrator observes, ‘that this greatest, and strangest, of all mankind’s legacies should have been created entirely accidentally’ (p. 570). As a highly complex entity, the sphere draws our attention to the sense of insignificance that characterizes the novel’s portrayal of humankind. The fact that during its visit to the Earth it encounters the brainless Ultimate and decides that such a simple creature could never have been capable of designing a conscious machine points to the transient nature of our species in the larger scheme of things and to the unpredictable effects of global disasters on the course of evolution.

*   *   *

Interestingly, the dispute between neo-Darwinists and their critics concerning the roles of selfishness and cooperation in evolution is alive not only in academic journals and popular science books but also in contemporary narrative fiction. Just as we can find portrayals of evolutionary issues that align themselves with neo-Darwinist views, such as Daniel Hecht's *The Babel Effect*, so there are novels that seek to challenge them. Representing the latter category, the American science fiction author Greg Bear approaches the ambiguities of Steven Best and Douglas Kellner's postmodern adventure in his books, of which many feature explicit biological themes. For instance, focusing on the unpredictable effects of genetic engineering, *Blood Music* raises questions about the same issues as Simon Mawer's *Mendel's Dwarf*: the ethics of genetic engineering, the hubristic desire of scientists to master natural processes, the opposition between free will and biological determinism, and the nature of human identity. However, by virtue of dealing with these topics through the genre of science fiction, Bear is able to take their treatment much further than Mawer. Whereas the technological means of genetic engineering in *Mendel's Dwarf*, abortion and artificial insemination, have been established as parts of everyday life in contemporary society, *Blood Music* explores the more futuristic and hypothetical ways of manipulating the human genome. *Darwin's Radio* in turn offers a vision of the evolutionary destiny of humankind by depicting the outbreak of a global viral disease. It suggests that instead of being a random affair, evolution is actually a self-directing process that produces mutations in the genetic make-up of the species for some unknown purpose. All in all, Bear depicts evolution as a fundamentally unpredictable process powered by cooperative, hierarchically organized genes. Because his representation of biology in both novels places a strong emphasis on the cooperative skills of genes and the unpredictable nature of evolution, it owes much more to the ideas of Gould and Margulis and Sagan than those of Dawkins. That is, he shifts the focus from Dawkins's idea of 'blind' evolution to the notion of evolution as a collective enterprise that has a specific yet unpredictable goal.

The first half of *Blood Music* follows the attempts of a California-based scientist named Vergil I. Ulam to create a new life-form through 'biologics',[30] a branch of genetic engineering that aims at manufacturing 'autonomous organic computers' (p. 15). Ulam's maverick research eventually clashes with the commercial aims of his employers, and he is forced to leave the company he is working for. In order to save the results of his research, he injects the engineered cells, the computers, into his own blood. Unable to predict the consequences of his act, Ulam soon begins to feel that he is losing control: the lymphocytes in his bloodstream appear to become more and more intelligent, and he realizes that he has become 'less a creator and more a servant' (p. 22) of the engineered cells. Like Dawkins's selfish genes, the genes in these cells transform from the passive building blocks of Ulam's body to active agents that proceed to rebuild him both physically and mentally, forcing him to view the new situation in terms of a struggle between his own will and the will of the genes:

> Vergil slammed his fist on the edge of the table. 'They made me do it! The goddamn genes!'
> 'Why, Vergil?'
> 'So they won't have to rely on us anymore. The ultimate selfish gene. All this time, I think the DNA was just leading up to what I've done. You know. Emergence. Coming out party. Tempting somebody, anybody, into giving it what it wanted.' (p. 66)

In this dialogue we again encounter Dawkins's anthropomorphized gene, whose intentional, active nature is evident in the verbs *lead up to*, *tempt*, and *want*. As in Dawkins's inversion of the hierarchy between the whole and its parts, Ulam appears to have become a vehicle

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[30] Greg Bear, *Blood Music* (New York: Arbor, 1985; London: Gollancz, 1986), p. 14. Further references to this book are given in parenthesis.

for the selfish ends of his genes to such an extent that he does not seem to be responsible for his actions anymore.

However, although Ulam's acts might be directed by intelligent entities, the so-called noocytes, his description of them as essentially selfish beings is to some extent undermined by the narrator's portrayal of their activities. Following the takeover of Ulam's body, the imperialistic noocytes rapidly and radically extend their territory by conquering the bodies of more or less everybody in North America, thus forming a huge blanket of biomass — an amorphous mass created by mutated human bodies — over the continent. After Ulam himself is absorbed by the biomass, his colleague Dr Michael Bernard senses his own transformation in terms of being inhabited by beings that are essentially cooperative, not selfish:

> This is now the basis of his being, the flow and electric sensation of pure life. He is aware of the knife-edge chemical balance between animation and dead jelly, with its roots in *order*, hierarchy, interaction. Cooperation. He is individual and, at the same time, he is each of the fellows of his team, the other hundred-cell clusters downstream and upstream. (p. 200; emphasis original)

As this passage shows, the effectiveness of the noocytes is based on controlled cooperation rather than on the individualistic efforts of the Dawkinsian genes. In fact, in their 'society' inside the biomass, selfish behaviour is not tolerated but promptly terminated: the noocytes 'send tailored phages after cells that don't interact properly. Viruses specified to individuals or groups. No escape' (p. 79). Hence, the noocytes are very much social creatures that through cooperation act for the benefit of the whole.

The passage cited above also implies that the structure of the noocyte society to a certain extent resembles Margulis and Sagan's holarchical model of the ecosystem. Instead of the whole and its parts being subjected to one another, an individual noocyte is simultaneously a part and the whole, as both are continuously being permeated by information in the bloodstream. As such, noocytes neither are individuals nor do they form a single consciousness. More than anything, individuality in the noocyte society refers to the way in which a particular cell cluster handles the assignments given to it, as is evident in the noocytes' answer to Bernard's questions about their nature and constitution:

> Perhaps this is what you mean by INDIVIDUAL. Not the same as single mentality. You are aware that cells cluster for basic structuring; each cluster is the smallest INDIVIDUAL. These clusters rarely separate for long into single cells. Information is passed between clusters sharing in assigned tasks, including instruction and memory. Mentality is thus divided between clusters performing a function. Important memory may be *diffused* through all clusters. What you think of as INDIVIDUAL may be spread throughout the *totality*. (p. 174)

Just as the various parts of the ecosystem in Margulis and Sagan's metaphor of life as a fractal of nested constituents, so individual units in the noocyte society, such as cell clusters, can be regarded as both parts and wholes, depending on which angle they are viewed from. For instance, from the viewpoint of command clusters, which issue orders to cell clusters beneath them, cell clusters are parts. However, from Bernard's viewpoint, command clusters are parts because for them he represents the 'supreme command cluster' (p. 173). Similarly, Bernard himself can be thought of as being a part of still larger units, such as various groups, society, the planet, and the universe.

In this sense, Bernard exists simultaneously at two interconnected levels. On the one hand, he is the 'huge Bernard' that examines the changes taking place in his body, while on the other hand, he 'can feel there is actually a human being on the level of the noocytes — himself' (p. 201). Significantly, the relationship between the two levels is not characterized by the use of exploitative strategies, as in Dawkins's portrayal of the relationship between individuals and their genes, but by mutual affection:

> [Bernard] is like an initiate suddenly inspired with the breath of God in a monastery. The monks gather, starved for a touch, a sign of redemption and purpose. It is intoxicating. He loves them, because they are his team; they are more than loving to him, because he is the Source. (p. 202)

Instead of parts dominating the whole as in Dawkins's theory, Bear's portrayal suggests a more balanced relationship between the two. Note how the last sentence describes the relationship between the individual and the noocytes through an antimetabole suggesting co-dependency. So, in this kind of holarchical model neither the individual organism nor its constituent parts can be considered primary in regard to each other. As the lengthy discussions between Bernard and the noocytes imply, the organism and its parts are engaged in a dialogue in which both sides are trying to gather information about each other rather than attempting to dominate each other.

As Bernard becomes more and more integrated into the society in his blood, his identity seems to become increasingly diffused, so that instead of remaining a single individual, eventually 'there are many Bernard' (p. 210). Indeed, reminiscent of Margulis and Sagan's metaphor of sentient symphony, the images and figures of speech *Blood Music* uses to describe the transformed form of humankind foreground the emergence of collective identity. 'There was a rhythm in his arms, in his legs', the narrator describes the sentiments of a character on the verge of transformation, 'With each pulse of blood, a kind of sound welled up within him as if an orchestra were performing thousands strong, but not in unison; playing whole seasons of symphonies at once. Music in the blood' (p. 106). Another character experiences the landscape, to which the biomass has given a surreal twist, as sound from ‘a big church choir with all its members’ mouths wide open, singing silence’ (p. 135).

By images such as these, the novel envisions the transformation of the species from an individual into a collective existence whose real nature remains hidden from those not yet absorbed into the noosphere, the realm of the noocytes:

> Was there politics, social interaction, in the noosphere? Were humans given an equal vote with noocytes?…
>
> Would there be conflict, revolution?
>
> Or would there be profound quiet — the quiet of the grave, because of a deletion of the *will* to resist? Not an important thing, free will, for a rigid hierarchy. Was the noosphere a rigid hierarchy, lacking in dissent or even comment? (p. 230; emphasis original)

The fact that the novel does not provide any answers to these questions suggests that Bear imagines the future of human evolution — in Gouldian fashion — as a more or less open-ended affair. In itself, the change cannot thus be judged in evaluative terms, and in the end we do not know whether its effect on humankind is for better or worse from our point of view (‘Things were changing, and that was disturbing — or exciting’ (p. 232)). Instead, *Blood Music* puts forth the idea that whatever direction evolution is taking, tomorrow’s humankind might not resemble humankind at the present moment. This is evident, for instance, in the fact that from human viewpoint, the symbolic landscape of the future appears to be more or less inhumanly insignificant:

> To tell the truth, Suzy McKenzie had been bored much of the time. She had never been much on imagination, and the stretches of rebuilt Manhattan she had traveled had not appealed to her much. The huge canal-pipes pumping green liquid from the river to the interior of the island, the slow-moving fan trees and propellor-trees [*sic*], the expanses of glassy-silver bumps, like collections of road reflectors, spread over hundreds of acres of irregular surface — none of these things had interested her more than few minutes. They had no relation to her. She could not begin to understand what they were for. (p. 232–33)

Viewed through the holarchical model of life, the situation of characters such as Suzy McKenzie is similar to the situation of noocytes. Noocytes are explorers for whom the human body and brain constitute the universe they explore, thus being a part of a much larger whole of whose dimensions or nature they only have partial knowledge. Similarly, the novel suggests that humans are a part of a larger whole of whose existence they are not aware. Although Bear does not explicitly depict this level, it is nevertheless implied that the scientists who study noocytes view the universe as a conscious entity that determines the direction of evolution: 'Bad hypotheses, those that don't fit what happens on our level, are rejected by the universe. Good ones, powerful ones, are incorporated' (p. 251).

This reading is supported not only by the scientists' vague references to a form of intelligent design but also by the names given to the concepts of the new evolutionary paradigm. For instance, *noosphere*, the thought universe in which noocytes operate, is clearly a reference to the theories of the Jesuit palaeontologist and philosopher Pierre Teilhard de Chardin, to whom some of the novel's scientists approvingly refer (Dr Bernard notes that 'Tielhard [*sic*] de Chardin […] might not be a bad guide [to understanding the noocytes]' (p. 186)). Inspired by Henri Bergson's *L'Evolution Créatrice* (1907), de Chardin argued that contrary to the view of Darwinism, the mental and social evolution of humankind is directed towards increasingly perfected forms in an explicitly teleological fashion.[31] Read in this light, then, the novel suggests that the biological and social evolution of the species has progressed to a point of dramatic upheaval — a sort of a creative catastrophe that in Gouldian terms suddenly punctuates the equilibrium of evolution — that

[31] 'Teilhard de Chardin, Pierre', in *Encyclopaedia Britannica* <http://www.britannica.com/eb/article-9071560> [accessed 30 July 2007] (page 1 of 1)

ultimately signals the beginning of a new stage in the process. Unlike de Chardin's theory, however, *Blood Music* does not really suggest that the next form of humankind will be better than the current one. Although there are benefits to living in the noosphere — instant communication by thought and the possibility of living the history of one's life again, for instance — essential human hallmarks such as a sense of a more or less unified and stable identity are irrevocably lost in the transition. In the end, the individual self is replaced by a self that is exclusively collective and infinitely shifting (communicating from the noosphere, Bernard asks, 'Which of me writes this? I do not know. There is no longer an original' (p. 239)).[32]

The notion of evolution progressing towards an unpredictable goal is also the controlling idea of *Darwin's Radio*, which, like *Blood Music*, focuses on the initial stages of an evolutionary transformation that manifests itself as an outbreak of a global viral disease. The novel begins with the anthropologist Mitch Rafelson stumbling on what are later confirmed as well-preserved bodies of direct ancestors of *Homo sapiens* in a cave in the Alps. At the same time the virologist Kaye Lang is engaged in investigating bodies found in mass graves in the Republic of Georgia, and learns that the graves contain the bodies of pregnant mothers. The link between these discoveries emerges when what appears to be an influenza-like disease, the so-called Herod's flu, begins to spread around the world. It is revealed that the disease is actually a sign of a genetic change that makes mothers give birth to babies without being inseminated. The babies are thus representatives of a new form of humankind, who have been eliminated because of their unnatural looks

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[32] In his analysis of Bear's novel Brian McHale calls this kind of self the 'centrifugal self' (p. 257). Often found in contemporary science fiction, it reconfigures the relationship between the self and the world through pluralization, as each different world is occupied by a different self (p. 253).

and behaviour. As the worldwide crisis escalates, the number of these new humans increases, with Mitch and Kaye becoming parents to one of them.

As in *Blood Music* Bear portrays evolution as a fundamentally self-directing affair that aims to change its own course. Yet, unlike the previous novel, which depicts the transformation in rather ambiguous terms, *Darwin's Radio* shows the outcome of the evolutionary transformation, and consequently suggests that the change is taking humankind towards an advanced form in the manner of Teilhard de Chardin's theory of evolution.

As I argued above, the emphasis given to unpredictable change and cooperation in *Blood Music* gives rise to a depiction of evolution that has more in common with Gould and Margulis and Sagan than Dawkins. In *Darwin's Radio* this tendency is even more pronounced, as there is explicit criticism of what can be regarded as distinctively neo-Darwinist principles. For instance, a character observes how Kaye's suggestion that the Georgian victims represent a case of a drastic evolutionary change triggered by an infections human endogenous retrovirus called SHEVA has 'really pissed off the old gradualists' and that 'Dawkins is beside himself'.[33] Moreover, in a Gouldian fashion the scientists speculate that evolutionary change takes place according to the principles of 'good old punctuated equilibrium' (p. 101), which stresses the role of fast adaptive speciation rather than gradual, cumulative change as the primary motor of evolution. Indeed, the fact that the mutated children are perceived as monsters by society points to the notion of evolution as a fundamentally unpredictable and disjunctive phenomenon.

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[33] Greg Bear, *Darwin's Radio* (New York: Ballantine, 1999), p. 99. Further references to this book are given in parenthesis.

However, unlike Margulis and Sagan and Gould, the novel at the same time suggests that evolution is a fundamentally self-directed process: like the hypothetical noocytes in *Blood Music*, SHEVA is an imaginary example of humans possessing an 'adaptive genetic computer' that 'only allows certain kinds of mutations to be used' (p. 101). This, of course, is yet another notion that goes against the basic principles of Darwinian biology: instead of random mutations blindly operating on matter, evolutionary changes are consciously activated processes that produce highly novel forms.

The novel's criticism of neo-Darwinism is also evident in one of its primary metaphors for life's organization: the network. 'Nerve cells are nodes in the brain,' Kaye notes, 'and genes are nodes in the genome, competing and cooperating to be reproduced in the next generation. Individuals are nodes in a species, and species are nodes in an ecosystem' (pp. 104–05). In the same way, she argues that the organization of all life is based on a hierarchical structure:

> All individual creatures are networks of cells. All species are networks of individuals. All ecosystems are networks of species. All interact and communicate with one another to one degree or another, though competition, predation, cooperation. All these interactions are similar to neurotransmitters crossing synapses in the brain, or ants communicating in a colony. The colony changes its overall behavior based on ant interactions. So do we, based on how our neurons talk to each other. And so does all of nature, from top to bottom. It's all connected. (p. 242)

As those in Margulis and Sagan's metaphor of the ecosystem as a fractal, the various levels of organization in Kaye's theory form a nested structure of interlinked parts. In other words, while neurons, genes, individuals, and species are all wholes in the sense that they form networks at their own levels, each one of them is a part of the whole 'above' them, just as the noocytes are parts of command clusters in *Blood Music*. Therefore, unlike in

Dawkins's model, the relationship between the part and the whole in the network metaphor is based on mutual interaction instead of one-way exploitation and control: 'Nodes or neurons in a network leading to neural net patterns, feeding back to the nodes the results of any network activity, leading to increased efficiencies for every node and for the network in particular' (p. 104). Parts thus work for the benefit of both themselves and the whole, while wholes work for the benefit of both themselves and their constituent parts.

It should be noted that like the portrayal of the noosphere's networks in *Blood Music*, the depiction of network activity in *Darwin's Radio* foregrounds the importance of cooperation for evolution through the idea that the various levels of organization are engaged in constant communication. The human genome, it is suggested, guides the evolution of the species by communicating through various means available to individual organisms. For instance, in a scene at the end of the book communication is portrayed taking place through pheromones, as Stella, the daughter of Mitch and Kaye, recognizes another representative of the new humankind by sniffing behind his ear (p. 522). In the same way, she awakens her parents to feed her in the middle of the night not by crying but by triggering her parents 'vomeronasal [the vomeronasal organ is an auxiliary olfactory sense organ located behind the nose and the mouth] response' (p. 512). As a retrovirus and a neurotransmitter, SHEVA too can be said to represent a means for human genome's communication with its surroundings: for Kaye it is through SHEVA that the genome 'is now responding to social change and the stress it causes' (p. 341). (In this sense, SHEVA is the Darwin's radio referred to in the title.) It is thus proposed that the current social change is caused by too much evolutionary competition, the mutation being a means of producing individuals who are cooperative rather than competitive.

In terms of depicting the human genome, then, it is not surprising that Bear's portrayal emphasizes its cooperative rather than selfish qualities. Kaye, whose view the novel encourages its readers to adopt, even thinks that the transposons (mobile sequences of DNA that position themselves within the genome of a single cell) in the hepatocytes (cells in the liver responsible, among other things, for protein synthesis and storage) are 'not selfish but selfless' (211). Hence, by using a strictly antithetical formulation, the novel refutes the neo-Darwinist assumption of genes selfishly manipulating their vehicles. Instead of trying to control the organism, retrotransposons 'guide the way proteins [become] living tissue. *Change* the way proteins [create] a living plant or animal' (p. 211; emphasis original). In this way, Bear suggests that instead of competing with each other, the various elements inside the individual organism actively cooperate for common goals.

Although the novel thus inverts neo-Darwinism's hierarchy between competition and cooperation, the outcome of the inversion actually points to one major similarity between neo-Darwinism and the new biology: both displace human beings from the centre of the evolutionary saga. This is suggested by the fact that Kaye, on whose theories the novel ultimately grounds its own view of evolution, regards SHEVA as confirming the existence of a 'species-level biological computer' (p. 245). Like Dawkins's selfish gene metaphor, this one points to the idea of evolution as being controlled by an inside agent not interested in the will and wishes of the individual organism. Hence, although the focus of interest has shifted from the level of genes to the level of the species, the implications appear to be the same: humankind's destiny is largely outside its conscious control. In this sense, *Darwin's Radio* repeats the idea presented in *Blood Music* that regardless of its technological sophistication, there is not much that humankind can do to influence the direction of evolution. ‘We’re mapping the factory floor of the living cell’, Kaye notes, ‘We’re discovering that nature is not just surprising, but shockingly unorthodox. Nature doesn’t give a damn *what* we think or what our paradigms are’ (p. 281; emphasis original). In other words, in Bear’s novels humankind is a vehicle for evolutionary change, and its destiny is inseparably linked to the unknown aims of the whole of which it is a part.[34]

* * *

To conclude my discussion of alternative portrayals of evolution in contemporary fiction, I examine a novel that approaches the issue from an angle somewhat different from the ones analysed above. Instead of focusing on evolution by examining the genetic make-up of the species, the American science fiction writer David Brin’s *Earth* features a portrayal of the evolutionary process of the species from the larger perspective of the whole ecosystem. Set in 2038, it portrays catastrophic happenings that threaten the survival of humankind, at the same time suggesting that the planet is a self-regulating entity similar to the one in James Lovelock’s Gaia theory.

In Brin’s novel the threat facing humankind takes the form of a black hole. Unlike those in space, however, this one has been created by human technology, and by human error it has fallen into the Earth’s core, threatening to destroy the planet within two years. The

[34] For some critics, the novel’s way of subjecting individual will to the will of the network constitutes its most controversial aspect. For instance, Lisa Lynch sees this as an example of ‘the fetishization of DNA’, while for Stephen Dougherty Bear’s metaphor of SHEVA as a species-level supercomputer amounts to ‘the depressingly familiar attitude in our contemporary culture that humans […] are either efficient or inefficient information-processors’. Lisa Lynch, ‘“Not a Virus, but an Upgrade”: The Ethics of Epidemic Evolution in Greg Bear’s *Darwin’s Radio*’, *Literature and Medicine*, 20 (Spring 2001), 71–93 (p. 89). Stephen Dougherty, ‘On Genetic Programs and Feedback Networks’, *Configurations*, 12 (Spring 2004), 263–85, (p. 279).

story consequently focuses on the attempts of scientists to locate the black hole — by drilling a long tunnel inside the Earth — in order to make it harmless. During their research the scientists discover that the core hides another black hole, which has apparently been created as a response to the artificial one. This raises the obvious question about the identity of the creator of the second black hole. The novel suggests that it has been created by the planet in order to protect itself from its most intelligent inhabitants. By such an environmental problem, then, Brin explores the relationship between the planetary whole and its parts, foregrounding the importance of viewing life holistically.

The exposition of ideas related to evolutionary theory in *Earth* to a considerable extent takes place in the context of the question about the relationship between humankind and the ecosystem. At the beginning of the novel, we are introduced to the evolutionary biologist Jen Wolling, who observes a genetically engineered mammoth-elephant infant called Baby:

> The pink-tipped trunk curled around her hand. She stroked it, tenderly, "You're awfully important to yourself, aren't you? And you *are* part of the whole."
> "But do you really matter, Baby? Do I?"[35]

The central question the novel thus poses concerning this relationship is whether certain species are indispensable from the viewpoint of the ecosystem in which they live. Like Margulis and Sagan's holarchical model of life, Jen's comment suggests that while species — and their individual representatives — may regard themselves as constituting more or less unified wholes, they are nevertheless parts of a hierarchical network. Moreover, as in the holarchical model, their relationships are based on mutual interaction, through which

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[35] David Brin, *Earth* (London: Orbit, 1990), p. 17; emphasis original. Further references to this book are given in parenthesis.

the part and the whole actively affect each other. Writing on the problem of how to recycle natural waste such as that produced by dead trees, Jen notes that

> One hundred trillion ants, secreting formic acid, help prevent a buildup which might otherwise choke the world beneath a layer of impervious, unrotting wood. They do this for their own benefit of course without thought of what good it does the Whole. And yet, the Whole is groomed, cleaned, renewed. (p. 27)

Here the relationship between the whole and its parts is presented in terms of reciprocity (the last two sentences suggest antimetabole as the linguistic form embodying the underlying logic of Jen's scientific philosophy): the forest provides the ants with a niche in the evolutionary struggle while the ants contribute to the health of the forest. Although the relationship between the planet and humankind is in many ways similar, it should be noted that as animals, both the infant mammoth and the ants are unconscious of their role in the larger scheme of things, whereas humans such as Jen are conscious of their position in relation to the whole, hence facing the conflict between their ethical ideals and selfish interests.

After introducing the question about ethical responsibility towards the whole, the novel, like Margulis and Sagan, goes on to suggest that in the end it must be the whole that matters more than the individual parts. This view is evident especially in the case of the character of Daisy McClennon. A daughter of an enormously wealthy and influential family, she is determined to save the planet from being damaged by humankind, which she sees as 'a parasite' (p. 666) consuming the vitality of its host, by using special military resonators whose beams can be tuned to kill only bipeds. Daisy's aim is to reduce the number of humans from ten billion to ten thousand, which she sees as an amount fit to be supported by the ecosystem. More specifically, the mass extermination of humankind is an attempt to preserve species on the brink of extinction, such as ‘the few remaining orangutans’ (p. 670) in Sumatra and ‘a few forests’ (p. 673) in Central America, or simply to seek ‘just vengeance for the slain manatee, reprisal for the long-dead moa, vindication for vanished condors’ (p. 667). The narrator’s diction implies that Daisy’s obsessive concern for things that are no longer important is short-sighted from the perspective of the whole ecosystem. Not really in control of the powerful technology in her hands, she accidentally destroys various geographical areas around the globe, thus in the end doing more harm than good.

By portraying Daisy’s actions as misguided and selfish, the novel establishes a link between the question about the well-being of the whole and the problem concerning the relationship between competition and cooperation, or selfishness and altruism. This is manifest, for instance, in a subplot in which a character called Nelson Grayson, an uneducated keeper in a wildlife preservation park in Africa, becomes Jen Wolling’s student. A part of Nelson’s curriculum features the study of evolutionary theoretical views, and he soon becomes acquainted with the neo-Darwinist model of evolution. ‘For years,’ he learns, ‘many thought it was *species* that adapted. But evidence later supported the “selfish gene” model — that *individuals* act in ways that promote success for their descendants, caring little for the species as a whole’ (pp. 218–19; emphases original).

However, although Nelson is introduced to the basics of neo-Darwinist thought, the novel suggests that on the overpopulated Earth, such thinking is no longer a plausible alternative in terms of survival. As I noted above, Daisy McClennon is essentially selfish because she refuses to compromise, forcing her own vision on the world with disastrous results, even though she sees herself acting for the benefit of the ecosystem. In contrast, Jen’s view of evolution holds that given the genetic make-up of humans, it is possible for individuals to exhibit behaviour that surpasses the concern for immediate, selfish needs:

This latter view of evolution — that it includes a place for kindness and cooperation — certainly is an attractive one. Don’t all our moral codes stress that helping one another is the ultimate good? We’re taught as babes that virtue goes beyond mere self-interest … (p. 221)

An example that illustrates this thesis can be found in another subplot. It features the story of three youths who appear to lead rather meaningless lives in the streets. Wanting to change the course of his life, one of them, Roland Senterius, joins a unit in global peacekeeping forces that is given the task of emptying a warehouse containing illegal merchandise, such as elephant tusks and tiger skins. While carrying out this task, Roland accidentally discovers the hiding-place of the merchant, and is taken hostage by him. In the ensuing battle the merchant wounds Roland’s comrades who have come to look for him, and Roland, desperate to save the lives of his friends, assaults the merchant and gets killed.

The impulse to act altruistically is also evident in the story of another one of the youths, Crat. Searching for employment at sea, Crat becomes a deck hand on a ship. In an accident he and a group of other hands are swept off the deck into the sea by a loose sail. Unexpectedly, Crat’s life is saved by a member of another species: a dolphin pushes him to the surface just as he is about to drown. As soon as he is out of danger, Crat in turn risks his own life by saving a man who has become trapped in a net. Although Crat’s act could be seen as an example of altruism, it is not entirely clear whether the dolphin acted out of concern for a member of another species — the narrator does suggest that the event might be regarded as an example of disinterested altruism, as from Crat’s point of view the dolphin's 'eye seemed to sense something — his realization [of being saved by it] perhaps' (p. 452).

In fact, inverting the neo-Darwinist hierarchy between selfishness and altruism, the novel proposes that in some cases seemingly selfish behaviour may entail genuine altruism. For instance, a character named Sepak observes how various species of birds interact with each other in a New Zealand forest as follows:

> Small, blue-feathered birds dove straight into the humus, flinging leaves and twigs as they chased fleeing insects. Above these, a larger, white- and yellow-plumed species hovered, diving to snatch anything stirred into the sight by the bold blue ones. Other varieties swarmed the trunks and looping tree roots. It was amazing to witness how the species cooperated, like members of a disciplined jungle cleanup squad.
>
> Then Sepak noticed some of them squabbling, fighting over this or that squirming morsel, and revised his first impression. The white-and-yellow birds were *opportunistic*, he now saw, taking advantage of the smaller ones' industriousness. He watched a black-tailed root hopper swipe a tidbit already wriggling between the jaws of an irate bird in bright orange plumes. Other breeds did the same, warily keeping an eye for each other while they worked over the trees' lower bark, gobbling parasites and protein-rich bugs before any competitor could get at them.
>
> This wasn't teamwork, then. It was a balance of threat and bluster and force. Each scrounger fought to keep whatever it found while taking advantage of the others. (p. 552; emphasis original)

As Sepak soon finds out, however, the birds are not being exceedingly selfish. While benefiting from the efforts of the smaller birds, the yellow-whites warn the entire community of an approaching hawk that preys on its members (p. 552). Hence, although competitive, the birds help each other for the common goal of maintaining their community, the competitiveness of the parts benefiting the whole by assigning different groups with different yet mutually supporting roles, without which the whole could not function properly.

Through such portrayals the novel attempts to avoid presenting the relationship between competition and cooperation in terms of a simplistic dichotomy. Reflecting Margulis and Sagan's use of synoeciosis in their description of life's diversity, *Earth* suggests that the complexity of the ecosystem is a product of creative interaction between the two. In fact, Brin introduces the idea that thinking in terms of dichotomies, such as the one between competition and cooperation, may prevent us from seeing and experiencing that diversity in depth. For instance, Jen argues that humans possess neither exclusively unified nor fragmented selves, but something in between: 'each of us is both many *and* one, all at the same time' (p. 501; emphasis original). Like cells and individual organisms, which are driven by the interaction of competitive and cooperative impulses, the human mind contains various subselves that continuously compete and cooperate with each other. Just as Margulis and Sagan, Brin makes use of synoeciosis in order to describe the coexistence of the two seemingly antagonistic impulses:

> *Our subselves usually aren't distinct, except in multiple personality disorder. Rather, a normal person's drives and impulses merge and cleave, marry and sunder, forming temporary alliances to make us feel and act in certain ways.* (p. 572; emphasis original)

Thus, the novel introduces an analogy between the organization of life on the Earth and that of the human mind, implying that the processes taking place in those structures are motored by coexisting impulses that should not be regarded as antagonistic but complementary. This foregrounds the novel's desire to see things holistically — Jen notes that one important function of human consciousness is to expose the various subselves and negotiate between them, with the result of '*neurosis* [losing] *most of its power* […] *as soon as all the mind gets to see those dark secrets one isolated part had kept hidden from the rest*' (p. 573;

emphasis original). Similarly, the new kind of unity, born out of the chaos caused by the catastrophic events, is unity in multiplicity that features all 'the little noisy, argumentative, even contradictory voices across the planet' (p. 696).

What these ideas emphasize, then, is that adopting a holistic worldview is essential for survival. In terms of the relationship between the whole and its parts, they also point to the suggestion that parts and wholes are never parts and wholes in isolation but that their 'identity' is always formed through their relationship to other parts and wholes. '*We need feedback from outside ourselves*', Jen notes, '*Life consists of interacting pieces, free to jiggle and rearrange themselves. That's how you make a working system, like an organism, or a culture, or a biosphere*' (p. 504; emphasis original). In Jen's case, for instance, this is illustrated by the fact that she arrives at an insight concerning the simulation capabilities of computers through her conversations with Nelson, who provides creative feedback for Jen's own thoughts, just as she helps develop Nelson's thinking. Similarly, in the case of the ecosystem, the novel foregrounds humankind's important role in giving 'feedback' to the planet. As highly intelligent and self-conscious creatures, humans provide the ecosystem with self-awareness, while the ecosystem's creation of the second black hole can be understood as its way of giving feedback to humans about using technological innovations in a life-threatening manner.

Hence, by envisioning an inseparable link between humankind and the planet, *Earth* imagines their relationship in terms of organic unity. Although threatening at first, the Beta black hole helps raise the level of the species' awareness of its surroundings. As in Greg Bear's stories, there is a change in the characters' views that accompanies the realization that an apparent catastrophe in itself entails a new beginning for the species, suggesting that we should not see the relationship in terms of opposition but unity. For instance, one of the characters points out that humans and the planet form a unified body of matter: ‘They’ll be her eyes, her hands, as she learns to shape and spread life to other worlds in the solar system’; humankind is also compared to the ‘body’s white blood cells’ (p. 715). In the context of our discussion of the relationship between the whole and its parts, such personification indicates that the nature of this kind of unity is distinctly organic in contrast to the neo-Darwinist notion of individual organisms as more or less atomistic entities.

Also in terms of the question about the relevance of evolutionary biology to human identity, this represents an attempt to go beyond simplistic dichotomies. At first the idea of unification produces anxiety because mind has been accustomed to function on the basis of the logic of either/or. Like Bear’s vision of humankind being transformed into a vast network of thought, in *Earth* the idea that humans are absorbed into a novel planetary consciousness arouses concern in the minds of some of the characters. Nelson, for instance, voices his anxieties by making a comparison between individuals and thoughts:

> Competition and cooperation … yin and yang … Each of us participatin’ in the debate is like one of the thoughts that bubble and fizz in my own head — whether I’m concentrating on a problem or daydreaming at a cloud. Does one particular thought worry about its “lost independence” if it realizes it’s part of something larger? (p. 697)

Although the novel does not venture to show what life is like for humankind on the new Earth, the holarchic model it espouses could be thought of as a negotiation between the polar opposites of extreme individualism and collectiveness. While *Earth* emphasizes the importance of cooperation for common aims, it also stresses the need to accept multiplicity in order to avoid rigidity of thought and action in the manner suggested by Margulis and Sagan’s metaphor of sentient symphony. Indeed, the way in which the story is structured around widely different characters is in itself an example of the dissonant coexistence of multiple views. For instance, both Daisy McClennon and Jen Wolling are intent on improving the condition of the environment, although their methods of doing this are completely different. So is the engineer Logan Eng, Daisy's former husband, who uses technology as a means of coming up with novel solutions; he forms a practical contrast to the technology-loathing Daisy and the theoretically oriented Jen by being more concerned by the 'hows' than the 'whys'. In addition, the novel depicts at length the conflicting views of groups such as the Ra Boys, who worship the Sun; the North-American Church of Gaia, whose members regard the planet as a living entity; the youthful Settlers, who seek to emigrate to less populated areas in order to escape the control of elderly citizens; and the neo-Gaian radicals such as Daisy, who regard humankind as a threat to be eliminated.

Thus, instead of seeking to make explicit value judgements on the various ideologies endorsed by its characters, *Earth* argues that 'each extreme was completely correct in its way, and each just as completely wrong' (p. 697). Just as in the case of competition and cooperation, for instance, Nelson is introduced to the paradoxical idea that capitalism and socialism, and religion and agnosticism are only apparently opposed to each other (pp. 378–79). By suggesting that none of the views represented by the various characters should be taken as a single, monolithic truth, Brin, like Margulis and Sagan, foregrounds the importance of multiplicity for evolution. The apparently dissonant voices of the various ideologies, after all, signal that the planet is — literally — alive and about to reach self-awareness through the conflicting viewpoints of its inhabitants.

*   *   *

The above analyses illustrate how contemporary fiction has responded to the ideas of the new biology. Stephen Baxter's *Evolution* offers a view of the evolution of the human species that is in accord with Stephen Jay Gould's metaphor of life as a branching bush: through its structure and the catastrophe motif, it presents evolution as a fundamentally unpredictable affair in which humankind is just another species on its way to extinction. In contrast, Greg Bear's *Blood Music* and *Darwin's Radio* depict evolution as a self-directing process, but nevertheless align themselves with the new biology through imagery that suggests cooperation rather than selfish competition. Like Bear, David Brin in *Earth* aims to present a holistic view of the whole and its constituent parts. By extensive explications of scientific theories and numerous characters, it proposes that the whole consists of parts that in many cases embody opposite qualities but still function on the basis of complementarity.

4.4 Evolutionary Biology: Conclusion

In this chapter I examined the representation of evolutionary biology in contemporary popular science writing and literature. Focusing on the debate between neo-Darwinism and the new biology, I discussed how the conflicting views understand human identity, as they usually emphasize the importance of either selfishness or cooperation.

In 4.2 I considered Richard Dawkins's popularization of evolutionary biology in *The Selfish Gene*. I showed how the figures of speech used by Dawkins help him invert the traditional relationship between the organism and the gene and argue that the latter is the primary agency behind the activities of the former. Based on especially metaphor and analogy, Dawkins's rhetoric strongly contributes to the displacement of the individual organism from the centre of contemporary biology. They also give his brand of neo-Darwinism its distinctively reductionistic sense, as most of them point to the level of genes as the fundamental level of explanation in evolution, a feature comparable to the tendency in modern physics to isolate increasingly elementary building blocks of matter. In terms of human identity, the notion that the basic building blocks of organisms are selfish leads to a view characterized by the conflict of nature and nurture: *The Selfish Gene* suggests that while humans are genetically programmed to be selfish, they can through education learn altruism, thus overcoming the limitations of their biological inheritance.

I then analysed two literary responses to neo-Darwinist thought in Daniel Hecht's *The Babel Effect* and Simon Mawer's *Mendel's Dwarf*. Finding its conceptual basis in distinctively Dawkinsian ideas, Hecht's novel explores the question of human identity and implies that instead of being intentional agents in possession of free will, human beings are to a large extent motivated by causes beyond individual volition. At same time, however, it finds solace in these ideas, thus reflecting the anxiety caused by the inversion of the hierarchy between the individual organism and its constituent parts. Similarly, *Mendel's Dwarf* draws attention to the double edge of science and technology, and points to the ways in which they might liberate humankind from the tyranny of selfish genes. While science and technology offer unforeseen vistas for bettering the human condition by making possible the control of biological processes, the novel suggests that they might become potentially harmful if used to buttress ideologies that neglect the question of ethical responsibility in social issues.

In 4.3 I discussed alternatives to neo-Darwinism in the new biology. I first considered how Stephen Jay Gould's *Wonderful Life* seeks to distance itself from those evolutionary narratives that portray the present form of the human species as the culmination of historical change. Questioning the binary opposition between the extremes of wholesale determinism and complete chance, Gould argues that while the short-term direction of evolution may be predicted accurately, it is impossible to say what kinds of evolutionary pathways are taken over long periods of time. I then continued my discussion by analysing Lynn Margulis and Dorion Sagan's call for a holistic account of evolution in *What is Life?*. I observed how the authors combat what they see as neo-Darwinism's tendency to reduce evolution to a selfish struggle for survival by foregrounding the importance of cooperation and symbiosis for the development of life.

To a much larger extent than Dawkins's neo-Darwinism, the writings of Gould and Margulis and Sagan are indicative of the postmodern turn in biology. In terms of the stylistic elements of Gould's argumentation, metaphor and antithesis foreground the roles of temporal change and contingency, suggesting that catastrophic events are the true motor of evolution. Margulis and Sagan in turn employ a wider range of figures: with rhetorical help from metaphor, incrementum and gradatio, synoeciosis, and various types of repetition, they portray evolution as a phenomenon characterized by complexity, interaction, dynamism, holism, and self-organization. Moreover, a distinctive feature of Margulis and Sagan's use of figurative language is that it gives rise to the same kind of both-and logic that is evident in many popularizations of the new physics and chaos theory, proposing that seeming binary oppositions such as competition and cooperation are actually complementary pairs when viewed holistically.

After discussing the three representatives of the new biology, I examined literary responses to their ideas. Like Gould, Stephen Baxter in *Evolution* avoids presenting the development of species as a gradual process towards a predetermined goal by emphasizing the role of contingent, unpredictable local factors in it. Next I argued that Margulis and Sagan's holistic outlook is in sympathy with Greg Bear's depiction of biological issues in *Blood Music* and *Darwin's Radio* because the novels choose to foreground the role of cooperation rather than selfishness as the primary evolutionary strategy. Bear's work also draws attention to the unpredictable nature of evolution, just as Gould does. Similar ideas are at the heart of David Brin's *Earth*, which explores the relationship between the planet and its organic parts by suggesting that the parts act for the benefit of the whole as much as they act for the benefit of themselves. Moreover, like Margulis and Sagan, Brin attempts to reconcile the opposition between competition and cooperation, and proposes that they are complementary, equal features of the whole, thus championing the holistic logic of both/and.

5. Computers, Information Technology, and the Case of Artificial Intelligence

In terms of the question about the evolution of humankind, the final part of my discussion is a logical continuation of the issues addressed in the previous chapter. Is it possible, as some theorists now envision, that the future will see an intimate co-evolution of humankind and its machines, followed by their complete merging? Is it possible that computers will be intelligent in the same way as humans are intelligent, allowing them to solve problems and understand the subtleties of human language? In this chapter I focus on popular science writing and literature dealing with artificial intelligence (AI), the theory and development of computer systems and programs seeking to emulate human intelligence and behaviour, by examining how they approach the shared topic of human identity. As in my discussion on evolutionary biology, I have selected books that approach the subject matter from different angles. For instance, the first popular science book analysed in 5.2, Joseph Weizenbaum's *Computer Power and Human Reason*, argues that it would be not only impossible but also unethical to build machines for tasks requiring human intelligence. In the same way, Roger Penrose's *The Emperor's New Mind: Concerning Computers, Minds, and The Laws of Physics* (1989) claims that human thought processes contain elements that cannot be represented through algorithms, thus drawing a clear demarcation line between humans and computers. Opposing views are represented by Hans Moravec and Ray Kurzweil, who in *Mind Children: The Future of Robot and Human Intelligence* (1988) and *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999), respectively, argue on behalf of the post-humanist dream of merging human beings with machines.

Also contemporary fiction offers various kinds of responses to the question about the relationship between humans and their machines. As I will show in my analyses in 5.2 and 5.3, in fiction too it is possible to find approaches that roughly correspond to the dichotomy outlined above. For instance, Neal Stephenson's *Snow Crash* and Richard Powers's *Galatea 2.2* suggest that there is an unbridgeable gap between human and computer intelligence. On the other hand, the stories of Isaac Asimov and Philip K. Dick, Arthur C. Clarke's space odyssey tetralogy, and William Gibson's 'Sprawl' trilogy portray the merging of the organic and the artificial as the culmination of the co-evolutionary process, often drawing attention to its ambiguous results.

5.1 From Organic Evolution to the Co-Evolution of Humans and Machines

The origins of the current development in computer and information technology can be traced back to the Second World War. Developed for military purposes in the United States in the 1940s, the electronic digital computer has become an indispensable tool in contemporary society. With the introduction of the so-called fourth generation computers in the 1970s, which employ thousands of integrated circuits on a single microchip, and subsequently the Internet, many facets of today's society — communication, education, business, scientific research, and so forth — have to a considerable extent become computerized.

While this is rather self-evident, the really interesting questions at the present moment concern the future generations of computers, which in the visions of theorists such as Hans Moravec and Ray Kurzweil might be able to truly utilize artificial intelligence. Capable of human-like thought, future computers would be able to carry out tasks that require superior intelligence, including decision-making, diagnosis, pattern and speech recognition, and the translation of natural languages. (The development of artificial intelligence should be understood as an interdisciplinary effort that combines research done in fields as varied as physiology, neurology, psychology, linguistics, and mathematics.) In order to accomplish all this, intelligent computers would be required to behave as humanly as possible, understanding and responding to natural languages, and, perhaps, as in many science fiction stories, to eventually reach self-awareness.

As the focal issue concerning future computers deals with the modelling of human intelligence in machines, it is inevitable that questions about the relationship of humans and machines arise, inviting us to consider not only the possibilities offered by machine intelligence but also the definition of human identity. In addition to Moravec and Kurzweil, strong proponents of artificial intelligence such as Gregory S. Paul, Earl D. Cox, and Vernor Vinge have approached the situation by envisioning radical changes in human evolution and arguing that in the future the relationship between humankind and its machines will increasingly be based on mutual dependency, even to a point where the two will merge. Such visions are essentially visions of a post-human future, since they describe the fusion of human beings and machines as a means of overcoming the limitations of organic existence (Best and Kellner, *Postmodern Adventure*, p. 181). In *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (1999) N. Katherine Hayles defines the term *posthuman* as follows:

> First, the posthuman view privileges informational pattern over material instantiation, so that embodiment in a biological substrate is seen as an accident of history rather than an inevitability of life. Second, the posthuman view considers consciousness, regarded as the seat of human identity in the Western tradition long before Descartes thought he was a mind thinking, as an epiphenomenon, as an evolutionary upstart trying to claim that it is the whole show when in actuality it is only a minor sideshow. Third, the posthuman view thinks of the body as the original prosthesis we all learn to manipulate, so that extending or replacing the body with other prostheses becomes a continuation of a process that began before we were born. Fourth, and most important, by these and other means, the posthuman view configures human being so that it can be seamlessly articulated with intelligent machines. In the posthuman, there are no essential differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot teleology and human goals.[166]

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[166] N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999), pp. 2–3. Further references to this book are given in parenthesis.

Hayles notes that our attitude towards the idea of the post-human is characterized by ambivalence, as it simultaneously gives rise to the feelings of anxiety and delight (*Posthuman*, p. 283). On the one hand, the idea that humans increasingly merge with machines poses a serious threat to what she calls 'the liberal humanist subject' (*Posthuman*, p. 3), an individual in possession of a more or less immutable, natural, and rational self that functions on the basis of free will. On the other hand, the pleasure of the post-human derives from the notion of transgressing the boundaries of the liberal humanist self, which can be seen as a means of attempting to redefine the concept of the human (Hayles, *Posthuman*, p. 285). In the end, Hayles, who clearly acknowledges the pleasures of the post-human condition while recognizing the fact that there is no escaping embodied experience, concludes that instead of signalling humankind's end, the post-human stands for the end of the elitist liberal humanist self, which is ultimately a result of the self-conception of economically and socially privileged individuals (*Posthuman*, p. 286).

Like Hayles, Steven Best and Douglas Kellner argue that the shift from liberal humanism to the post-human has in fact been taking place since the end of the Second World War, as the values of the Renaissance and the Enlightenment have been extensively critiqued and questioned by various strands of postmodern thought. Unlike the self of classical humanism, they state, the post-human self is an entity 'immersed […] in history, social relations, and institutions, and embodied reality' (*Postmodern Adventure*, p. 195). Yet, as they go on to remind us, it should be noted that there is no single, monolithic post-humanism, just as there is no such postmodernism. Instead, there are various approaches and attitudes to the post-human: while at one end of the theoretical continuum we find 'radical deconstructive posthumanists, who reject altogether the legacy of humanism, the

Enlightenment, modern values and theory, the concept of progress, and a belief in some notion of agency', there are also 'moderate reconstructive posthumanists, who seek to rethink mind, body, and agency (and associated notions like reason and freedom) [...] and do not completely sever themselves from the modern legacy' (*Postmodern Adventure*, p. 197).

However, regardless of how one chooses to position oneself in this discussion, it is undeniable that the relationship between humans and machines is going to be more intimate in the future than it has been in the past. Although we do not have to agree with critics such as the historian of science George Dyson, who in *Darwin among the Machines: The Evolution of Global Intelligence* (1998) claims that the co-evolution of humans and machines is bound to replace the current form of humankind with increasingly intelligent machines, it needs to be recognized that in the future, the relationship between the two might have to be defined in terms of the collapse of the boundary separating the organic from the inorganic. Indeed, like Hayles above, Best and Kellner speculate that 'posthumanism unfolds as a symptom of an advancing technoculture where the distinction between biology and technology, never absolute, blurs significantly, resulting in both the technification of biology and the biologization of technology' (*Postmodern Adventure*, p. 182). In short, while technology takes on the qualities of organic life (robots 'learn' to simulate emotions, silicon chips 'evolve' by modifying their wiring, computer viruses 'infect' information processing systems, and so forth), biological systems are modified through the various forms of genetic engineering (Best and Kellner, *Postmodern Adventure*, pp. 182–84). For Best and Kellner, co-evolution at the turn of the millennium is thus best described as an interactive loop in which the boundary between the organic and the inorganic becomes increasingly blurred. ‘We’re becoming cyborgs and technobodies,’ they speculate, ‘while our machines are becoming “smart” and more human-like’ (*Postmodern Adventure*, p. 151).

5.2 Separating Men from Machines

Having briefly introduced the context for my discussion, I now turn to the debate concerning the co-evolution of humankind and computers by analysing views that postulate a qualitative difference between organic and artificial intelligence. According to the proponents of this position, the difference is a consequence of the idea that the mental functions and emotions characteristic of human beings cannot be wholly reduced to the kinds of algorithms that computers handle. For this reason, the critics of the strong position of artificial intelligence argue, it is impossible to teach computers to learn to become human in the same way as humans are taught to acquire certain skills, such as the use of language and the ability to make ethical choices.

5.2.1 'Man is not a machine': Reason and Judgment as Uniquely Human Qualities

The first book analysed in this section, Joseph Weizenbaum's *Computer Power and Human Reason*, offers a critical view of the development of artificial intelligence in the mid-1970s.[167] Born in Germany, Weizenbaum, who began his career in computer science

[167] For other contemporary critiques of AI, see, for instance, Hubert Dreyfus's *What Computers Can't Do: The Limits of Artificial Intelligence* (New York: Harper & Row, 1972). Discussing the relationship between human and artificial intelligence from the phenomenological (mainly Heideggerian) point of view, Dreyfus, like Weizenbaum, argues that humans handle information in ways that differ considerably from the linear,

already in the 1950s, is today known for his work on ELIZA, a computer program designed to understand natural language. In the introduction Weizenbaum observes that the impact ELIZA had on some scientists and researchers interested in machine intelligence was partly responsible for the book. While ELIZA's parody of a psychotherapist's responses to questions posed to it was so convincing that some psychiatrists thought the program could be developed into a tool for clinical use in hospitals lacking therapists, others found in it a solution for modelling natural language on computers.[168] In addition, Weizenbaum noticed that people experimenting with the programme often treated it as they would treat another human being (pp. 6–7).

In fact, Weizenbaum is not really interested in the computer as a physical product of technology but as an extremely powerful cultural metaphor. 'A major point of this book', he writes, 'is that we, all of us, have made the world too much into a computer, and that this remaking of the world in the image of the computer started long before there were electronic computers' (p. ix). In consequence, he argues, humankind has become to view both society and itself in terms that are above all 'rationalistic' and 'mechanistic' (p. 11). Thus, using the computer as a conceptual tool for approaching certain features in modern society, Weizenbaum wishes to combat the tendency to resort to the logic of calculation when reason and judgment are needed. In our modern society, he claims, this tendency has

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rule-based methods of computers. This discussion is developed further in *What Computers Still Can't Do: A Critique of Artificial Reason* (Cambridge, Mass.: MIT Press, 1992).

[168] Joseph Weizenbaum, *Computer Power and Human Reason: From Judgment to Calculation* (San Francisco: Freeman, 1976; London: Penguin, 1984), pp. 5, 7. Further references to this book are given in parenthesis.

manifested itself as a willingness to treat social, political, and historical phenomena as calculations governed by laws similar to the mathematical laws of nature (p. 14).

This is why he argues that the main problem underlying the issue of artificial intelligence concerns the computability of human thought. If human thought is reducible to logical formalism, there appears to be no qualitative difference between the human mind and computer logic. If, however, such reduction is not possible, then there must exist definite criteria for setting humankind apart from its data processing machines. From these considerations emerge the two main arguments of Weizenbaum's book: that there is a qualitative difference between humans and computers and that computers should not be given tasks that require the use of uniquely human faculties (pp. x, 13).

For Weizenbaum, development in the field of artificial intelligence has caused serious problems concerning the future relationship between humans and computers. These problems, he argues, will be evident especially in cases in which the supreme calculation power of the computer and the ability of AI to mimic human behaviour are allowed to take over from human reason and judgment, thus contributing to an increasingly mechanistic view of humankind and society. 'Ultimately a line dividing human and machine intelligence must be drawn', he writes, 'If there is no such line, then advocates of computerized psychotherapy may be merely heralds of an age in which man has finally been recognized as nothing but a clock-work' (p. 8). Evoking the negative associations linked to the Newtonian notion of the universe as a precise and predictable automaton through the familiar clockwork metaphor, Weizenbaum approaches the issue through two specific questions that he situates in context of the problem of the computer's ability to understand natural languages: Is it possible to formalize human language? Are there concepts and ideas whose meaning the computer is unable to grasp because they are unrelated to objectives peculiar to machines? (p. 197). In Weizenbaum's view, for many AI theorists the answer to the first question is an unproblematic 'yes', as they aim to

> build a machine on the model of a man, a robot that is to have its childhood, to learn language as a child does, to gain its knowledge of the world by sensing the world through its own organs, and ultimately to contemplate the whole domain of human thought. (pp. 202–03)

In this passage Weizenbaum argues that the thinking of the proponents of the strong AI hypothesis (the argument that some forms of artificial intelligence can become capable of reasoning, solving problems, and self-awareness) is based on a rather straightforward analogy between the development of human beings and computers. Note that in terms of argumentation, the sense of 'grandiose fantasy' (p. 202) that he links to the hope of computers attaining human-like intelligence is foregrounded by the use of incrementum: the smooth incremental series lists the general stages of the envisioned development in order to not affirm the vision of AI theorists but to reveal its simplistic and unproblematic logic. (I will give more examples of this analogy in my discussion on the arguments of Ray Kurzweil and Hans Moravec.)

After persuading his readers of the fallibility of such logic, Weizenbaum emphatically denies that the same learning processes could take place in both human beings and machines. 'Man faces problems no machine could ever possibly be made to face', he states, 'Man is not a machine' (p. 203). Although both human beings and machines are information processors, what ultimately separates the two from each other is their different ways of processing that information.

Not content with the analogy of AI theorists, then, Weizenbaum turns to the findings of neurology for evidence against the claim that the kind of information humans possess can be fully represented by computers. In his discussion on artificial intelligence, he notes that information processing performed by the human brain is a result of the activity of its two hemispheres. He goes on to describe the unconscious, which resides in the right hemisphere, as follows: ‘It is like a seething, stormy sea within us. Its waves lap on the borders of our consciousness’ (p. 219), while the border separating the unconscious from the conscious mind is later compared to ‘a stormy coastline’ (p. 280). The two similes have an important argumentative function in Weizenbaum’s discussion because they suggest that the very structure of the human mind sets certain limits to the modelling of its functioning. Weizenbaum elaborates on the comparison by describing what it means in practice:

> The lesson here is […] that the part of the human mind that communicates to us in rational and scientific terms is itself an instrument that disturbs what it observes, particularly its voiceless partner, the unconscious, between which and our conscious selves it mediates. Its constraints and limitations circumscribe what are to constitute rational […] descriptions and interpretations of the things of the world. These descriptions can therefore never be whole, anymore than a musical score can be a whole description or interpretation of even the simplest song. (p. 222)

As in the case of individuals’ inability to ever know the deepest motives behind their own actions in Michael Frayn’s *Copenhagen*, Weizenbaum’s comparison suggests that the violent sea of the unconscious can never be fully explored. In fact, the passage grounds this conclusion on the same kind of reasoning as Frayn uses: by making an implicit comparison between the study of the human mind and that of nature through the phrase *an instrument that disturbs what it observes*, it obviously alludes to the idea that our observations of quantum phenomena are bound to be partial because of the uncertainty principle. Hence, Weizenbaum argues that just as our observation of subatomic particles can never simultaneously reveal their momentum and location, so our explanations of the human mind can never exhaust its totality because of the essential incalculability of the unconscious.

The importance of this analogy is indicated by the fact that it is given an extended form at the end of the book. The function of the extension is to draw readers' attention to yet another major difference between humankind and its machines. Discussing the teaching of computer science, Weizenbaum claims that in order to set a good example for students, teachers must become whole, meaning that they must gain a sufficient amount of knowledge concerning not only the physical but also the mental world (p. 280). This effort is portrayed through a comparison that uses the imagery of the first part of the analogy:

> For the courage required to explore a dangerous coast is like the courage one must muster in order to probe one's unconscious, to take into one's heart and mind what it washes up on the shore of consciousness, and to examine it in spite of one's fears. For the unconscious washes up not only the material of creativity, not only pearls that need only be polished before being strung into structures of which one may then proudly speak, but also the darkest truths about one's self. (p. 280)

The extension likens humans to explorers who in charting inner territories must above all be courageous. Not possessing an unconscious, computers obviously cannot ever become explorers in the same sense. It is only human beings that seek to become whole — although through an effort that cannot be anything but partial, as the point about fully knowing oneself suggests — through self-knowledge. Hence, in Weizenbaum's view one of the crucial differences between the organic and artificial species is found in the drive towards the acquisition of such knowledge: while computers may be adept at calculation, they will never strive to know themselves by exploring what is hidden beneath consciousness and rationality.

An additional function of Weizenbaum's analogy is to stress the importance of the kind of moral courage that the author wants humans to show in the age of increasing computerization. The probing of the unconscious part of mind in this way finds its macroscopic equivalent in the facing of social fears caused by having to speak against instrumental reason. The imagery of exploration as facing the unknown therefore points to a crucial ethical imperative in *Computer Power and Human Reason*: as in Tom Stoppard's *Arcadia*, the proper measure of human courage is the willingness to act, no matter how hopeless the circumstances we find ourselves in are. 'The good of a moral act', Weizenbaum observes, 'inheres in the act itself' (p. 276). The link to the above analogy is established in explicit terms in Weizenbaum's comment that

> hardly anyone who reads these lines will feel himself addressed by them — so deep has the conviction that we are all governed by anonymous forces beyond our control penetrated into the shared consciousness of our time. (p. 276)

The diction of the passage shows that for him, society too has — in a metaphorical sense — a mind that continuously confronts itself in the form of its unconscious drives. By the comparison to the shared consciousness of society, readers are made to understand better the rationale behind Weizenbaum's proposed means of dealing with the situation: raising the level of educators' awareness about what computers really are and what kind of logic they symbolize. In other words, people teaching computer skills need to make the unconscious elements conscious in order to reveal the true nature of the anonymous forces.

Although he has targeted the computer as a metaphor symbolizing the prevalence of instrumental reason in the modern world, Weizenbaum does not really offer his readers alternative metaphors for the kind of logic by which he would like to see society to function. He does, however, outline a portrait of an ideal teacher of computer science. After discussing the features that in his view an incompetent teacher possesses, he goes on to describe a teacher who is aware of what the computer metaphor truly means:

> If the teacher, if anyone, is to be an example of a whole person to others, he must first strive to be a whole person. Without the courage to confront one's inner as well as one's outer worlds, such wholeness is impossible to achieve. Instrumental reason alone cannot lead to it. And there precisely is a crucial difference between man and machine: Man, in order to become whole, must be forever an explorer of both his inner and outer realities. His life is full of risks, but risks he has the courage to accept, because, like the explorer, he learns to trust his own capacities to endure, to overcome. What could it mean to speak of risk, courage, trust, endurance, and overcoming when one speaks of machines? (p. 280)

Again note how Weizenbaum continues to use the familiar concepts of psychology as he paints a picture of his ideal teacher. By yet another simile he compares the teacher to an explorer who has the necessary courage to confront not only his inner demons but also the ones plaguing society at large. It is thus the image of the explorer that Weizenbaum gives his readers as symbol of defiance of the computer metaphor. Note also how crucial this image is in terms of his definition of the fundamental difference between humans and machines: it is significant that all the qualities he ascribes to the explorer are qualities that machines cannot possibly have because machines are not by any definition social creatures. Even if we could describe them the meanings of the concepts listed in the last sentence, they could never learn about them in the same way that human beings do: through their senses and bodies. (Weizenbaum's use of the interrogative sentence at the end of the passage functions as an affirmation of this insight, and could be identified as an instance of erotema, the rhetorical question, as he does not proceed to develop the idea by offering an answer.)

The fact that Weizenbaum's argument places much weight on the role of the unconscious is also evident in his discussion on the relationship between rationality and intuition. He notes that AI enthusiasts make a clear opposition between what they perceive as rationality and mindlessness, indicating that in their thinking rational endeavours, such as science, have absolutely nothing to do with intuition (p. 255). For Weizenbaum, however, rationality and intuition are not by definition diametrically opposed concepts: they are just two sides of the same coin. Unlike many other writers studied here who undo antitheses by subjecting the opposites to an all-inclusive third term, he does not engage in such rhetorical manoeuvres but simply points out that 'rationality may not be separated from intuition and feeling' (p. 256). He does, however, employ antithesis in conjunction with this discussion, stating that 'I combat the imperialism of instrumental reason, not reason' (p. 256) and that '[the rhetoric of the technological intelligentsia] urges instrumental reasonings, not authentic human rationality' (p. 253). By using antithesis to separate the general concept of reason into two distinct subtypes, the reason of 'the artificial intelligentsia' (p. 179) and the reason that recognizes the dangers of the logic of computability and calculation, Weizenbaum is able to create an argument that draws a clear line of demarcation between the ideals of technocracy and humanism.

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The argument that there is a qualitative difference between humans and computers also forms the main thesis in the English mathematical physicist Roger Penrose's *The Emperor's New Mind*. Famous for his achievements especially in the fields of general relativity and cosmology, Penrose has in addition studied the link between physics and consciousness. Like Joseph Weizenbaum, he attacks the claims of the proponents of the strong AI hypothesis by arguing that human consciousness is not limited by the same factors as systems using only formal logic. Unlike Weizenbaum, however, Penrose claims that the questions concerning the development of artificial intelligence should be approached by studying the relationship between the human mind and the laws of physics. In his argument he is therefore mostly concerned with the questions whether it is possible to separate mind from its physical basis and whether mind is governed by the same physical laws as matter in general.[169] While discussing these questions in terms of the differences and similarities between computers and humans, Penrose focuses on the same critical distinguishing features that Weizenbaum speaks of in *Computer Power and Human Reason*: consciousness and judgement. He arrives at the conclusion that making judgements, which involves separating truth from falsehood in situations in which such action is required, is 'the hallmark of consciousness' (p. 412). Consequently, since judgement cannot be reduced to algorithmic language, Penrose's main argument in *The Emperor's New Mind* is that 'there is an essential *non*-algorithmic ingredient to (conscious) thought processes' (p. 404; emphasis original).

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[169] Roger Penrose, *The Emperor's New Mind: Concerning Computers, Minds, and The Laws of Physics* (Oxford: Oxford University Press, 1989), pp. 3–4. Further references to this book are given in parenthesis.

Penrose begins his discussion by considering the possibility suggested by the strong AI theory that 'mental qualities of a sort can be attributed to the logical functioning of *any* computational device, even the very simplest mechanical ones, such as a thermostat' (p. 17; emphasis original). In short, the position of strong AI maintains that all kinds of mental qualities in humans — thoughts, emotions, intellect, awareness, and so forth — can be written as algorithms, processes or sets of rules used in calculation and problem-solving that the brain implements in the manner of a computer (p. 17). As strong AI regards the algorithm as the most important factor in the representation of mental states, it in Penrose's view tends to downplay — if not dismiss altogether — the physical setting in which algorithms are embodied (p. 21). Accordingly, following the critique of the philosopher John Searle against the strong version of AI, Penrose notes that strong AI gives rise to pronounced, Cartesian mind-body dualism: 'The point is that the mind-stuff is not supposed to be composed of matter, and is able to exist independently of it. The mind stuff of strong AI is the logical structure of an algorithm' (p. 21).[170]

Penrose also points out that the dichotomy between mind and matter in strong AI is implicitly if not explicitly a qualitative one. He notes that in strong AI, the metaphorical hardware of body is considered unimportant in regard to the equally figurative software of mind (p. 24). Penrose discusses how this division is linked to the question about human identity, noting — like Ray Kurzweil and Hans Moravec, the proponents of strong AI

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[170] By his famous thought experiment of the so-called Chinese room, Searle seeks to argue that the processes of the human mind involve more than just computation: although it would be possible to say that a machine such as the computer successfully performs algorithms describing a language, we cannot say that computers are truly able to understand languages in terms of the meaning of their words. David Cole, 'The Chinese Room Argument', in *The Stanford Encyclopedia of Philosophy*, online edn, ed. by Edward N. Zalta, 2004 <http://plato.stanford.edu/entries/chinese-room> [accessed 30 July 2007]

theory discussed in 5.3 — that it is not plausible to suggest that identity could ever be defined on the basis of the material of which the human body is composed. Because old cells are continuously replaced by new ones, the physical composition of body changes all the time, thus eliminating the possibility of equating identity with the hardware (pp. 24–25).

The second reason for why we should not identify identity with bodily existence is for Penrose found in the laws of quantum physics. Noting how certain types of particles are identical with each other, he goes on to propose that

> If an electron in a person's brain were to be exchanged with an electron in a brick, then the state of the system would *be exactly the same state* as it was before, not merely indistinguishable from it! The same holds for protons and for any other kind of particle, and for whole atoms, molecules, etc. If the entire material content of a person were to be exchanged with corresponding particles in the bricks of his house then, in a strong sense, nothing would have happened whatsoever. What distinguishes the person from his house is the *pattern* of how his constituents are arranged, not the individuality of the constituents themselves. (p. 25; emphases original)

Note how the passage in its last sentence uses antithesis to capture the essential dichotomy in the strong position of AI: rather than viewing information as a phenomenon linked to a particular material base, the strong position effectively removes it from its physical context. By such an argumentative manoeuvre, proponents of the strong position have suggested that it might be possible to create a type of artificial intelligence that does not require a physical body in order to function. If we accept this claim, Penrose summarizes the implications of the argument that the hardware of the human body is dispensable, then it is possible to conclude that mind is essentially a digital computer whose algorithms we may learn to know and thus simulate on the computer (pp. 28–29). However, he does not see this as a plausible scenario because for him thinking arises from the biological and chemical configuration of the brain, thus arguing for a link between mind and body (p. 28). Like Weizenbaum, then, Penrose combats the power of the computer metaphor by trying to show the faulty logic behind it.

Penrose begins his discussion of the physics of mind by contemplating the possibility that the human brain might be functioning on the basis of an algorithm. He goes on to state that if this is indeed the case, the reason for the brain's algorithmic constitution must lie in the mechanisms of natural selection, as the development of increasingly efficient algorithms would have been beneficial for the survival of the species (p. 414). While he considers this to be true to a limited extent, Penrose argues that natural selection cannot be held responsible for the human ability to make judgements concerning the effectiveness of algorithms. He then points out that computer programmes — which, of course, are examples of algorithms — have not been created by other computer programmes but programmers who possess the needed ingenuity to write them. 'If one believes', he writes, 'that the actions of the computer programmers' consciousnesses are themselves simply algorithms, then one must, in effect, believe that algorithms *have* evolved in just this way' (p. 414; emphasis original). This too, however, is from Penrose's viewpoint invalid reasoning because computer programmers need to judge the efficiency of their programs through judgments that cannot be algorithmic in themselves, and he concludes by noting that 'in order to decide whether or not an algorithm will actually *work*, one needs *insights*, not just another algorithm' (p. 415; emphases original). In this way, Penrose uses antithesis to epitomize his conclusion, making a clear-cut conceptual gap between human insights and machine-read algorithms.

Penrose goes on to illustrate his claim that human consciousness contains non-computable elements by discussing the phenomenon of mathematical insight, the ability to 'see' things in a momentary, epiphanic state of understanding. After discussing Henri Poincaré, who allegedly discovered the definition of Fuchsian functions while entering a bus, and his own way of discovering the solution to the problem of black-hole singularities, Penrose notes that along with the sense of scientific beauty, they represent examples of 'the instantaneous judgments of inspiration' (p. 421) that often precede the more rigorous mathematical argumentation. Then he comes to the conclusion that 'these judgements […] I consider to be the hallmark of conscious thinking' (p. 422). In other words, Penrose argues that in such experiences it is consciousness that functions as an 'arbiter' separating the workable unconscious ideas from the unworkable ones — while the unconscious is responsible for the 'putting-up' of ideas, the conscious mind directs their 'shooting-down' (p. 422). Moreover, the fact that mathematical insights are often communicated non-verbally leads Penrose to speculate that 'such thinking might also have a non-algorithmic character' (p. 425).

Another area of human experience in which Penrose sees consciousness as having an important role is our experience of time. In particular, he argues against the view that humans respond to stimuli completely automatically in situations that require fast action (responses occurring within less than one or two seconds) (p. 442). Using table tennis as an illustrative example, he maintains that

> No doubt there is a lot of anticipation of what one's opponent might do, and many pre-programmed responses might be available to each possible action of the opponent, but this seems to me to be inefficient, and a *total* absence of conscious involvement at the time is something that I would find difficult to accept. (p. 443; emphasis original)

Rather than reacting as automatons, Penrose suggests, humans react as conscious beings, even though this might not always appear to be the case. The reason for this, he proposes, is that when trying to study consciousness, we refer to the normal, linear way of understanding temporal processes, thus imposing on the mechanism of consciousness a framework that in its simplicity does not fit it (pp. 443–44). In order to illustrate the implications of the statement that we often misperceive situations involving temporal progression, Penrose describes how musical compositions are born:

Listen to the quadruple fugue in the final part of J. S. Bach's *Art of Fugue*. No one with a feeling for Bach's music can help being moved as the music stops after ten minutes of performance, just after the third theme enters. The composition as a whole still seems somehow to be 'there', but now it has faded from us in an instant. Bach died before he was able to complete the work, and his musical score simply stops at that point, with no written indication as to how he intended it to continue. Yet it starts with such an assurance and total mastery that one cannot imagine Bach did not hold the essentials of the entire composition in his head at the time. Would he have needed to play it over to himself in its entirety in his mind, at the normal pace of a performance, trying again and again, and yet again, as various different improvements came to him? I cannot imagine that it was done this way. Like Mozart, he must somehow have been able to conceive the work in its entirety, with the intricate complication and artistry that fugal writing demands, all conjured up together. (p. 445)

In contrast to viewing consciousness as a phenomenon that requires a certain amount of time to activate, Penrose suggests that it is always present in the activity of our minds. By drawing an analogy between art and science, he suggests that musical composition and mathematical discovery are similar activities in the sense that in both there is the quality of conceiving everything at once, which makes it unjustified to equate the 'direction' of consciousness with that of temporal processes taking place in the world. Hence, consciousness is for Penrose a timeless phenomenon through which the human mind might conceivably establish a direct link with the Platonic realm of ideas (pp. 445–46).

Rhetorically speaking, Penrose's argument concerning human consciousness reverses some of the basic assumptions that have been presented of the human mind. For instance, whereas Weizenbaum regards the unconscious as the dark sea of mind that cannot be mapped in its entirety, Penrose envisions the conscious part of mind as the one that cannot be reduced to algorithmic description. In other words, while concepts such as *common sense*, *judgement of truth*, *understanding*, and *artistic appraisal* all indicate processes that require conscious thinking, unconscious processes are something that Penrose describes as 'automatic', 'following rules mindlessly', 'programmed', and 'algorithmic' (p. 411). Consequently, there is a reversal of the roles assigned to both, as he himself acknowledges:

> I […] suggest that, whereas unconscious actions of the brain are the ones that proceed according to algorithmic processes, the action of consciousness is quite different, and it proceeds in a way that cannot be described by any algorithm.
>
> It is ironic that the views I am putting forward here represent almost a reversal of some others that I have frequently heard. Often it is argued that it is the *conscious* mind that behaves in the 'rational' way that one can understand, whereas it is the unconscious that is mysterious. (p. 411; emphasis original)

By reversing the roles of the conscious and the unconscious parts of the mind, the passage establishes a sharp division between them. While Penrose does admit that such 'distinctions are not always very clear cut' (p. 411), he suggests that judgment and the other types of conscious thought are not reducible to algorithmic representation.

Penrose's emphasis on the conscious-unconscious dichotomy also characterizes much of his discussion on the relationship between the human brain and its computer models. He notes that behind the notion of the brain as a computer is the assumption that the neuron firing taking place in the brain and the way in which computers process information are analogous to each other (p. 395). 'It is easy to see', he writes, 'that a computer could simulate any such model of neuron interconnections; […] conversely, systems of neurons are capable of simulating a computer' (p. 395), thus using a loose antimetabole to illustrate the idea that the brain and the computer function in essentially similar manner. However, having introduced this as an exciting possibility, he goes on to argue that there are important differences between the two, so that on closer inspection the idea of equivalence becomes questionable. (In terms of its structure, Penrose's method of argumentation in *The Emperor's New Mind* tends to follow a pattern in which he first introduces the pros of the ideas of the supporters of the strong AI theory, and then proceeds to refute them by discussing their cons.) For instance, he notes that the outcomes of neuron firing are not always predictable, that the activity going on in the brain is very slow in comparison to the one in computers, and that the configuration of neurons is characterized by randomness and redundancy (p. 396). On the other hand, he claims, the brain is in some ways more complex than the computer, particularly in terms of the number of its neurons in comparison to the number of transistors in computers (p. 396).

Although these are important differences, Penrose finds even more significant ones in the concept of brain plasticity. Brain plasticity refers to the fact that the connections neurons establish with each other are not static but dynamic, making the configuration of the brain more flexible than that of computers (p. 396). Because the connections are constantly changing, Penrose sees brain plasticity as 'an essential feature' (p. 397) of its activity. He then notes that artificial intelligence research has tried to model the complexity of the human brain through parallel computing, which allows a vast amount of tasks to be performed separately on multiple processors for faster results (p. 398).

For Penrose, however, parallel computing does not prove the validity of the brain as a computer metaphor. In his view, the reason for this lies in the characteristic oneness of conscious thought, which suggests that instead of performing several tasks at the same time, conscious thinking focuses on one thing at a time (p. 399). In contrast, he argues, parallelism is a characteristic feature of actions that have become so mechanized and automatized — 'walking, fastening a button, breathing, or even talking' (p. 399) — that they can be carried out simultaneously. In this respect, parallelism is for Penrose a feature of unconscious rather than conscious action (p. 399). Although Penrose none the less considers the possibility that the conscious mind's oneness might be related to what he calls quantum parallelism, the notion in quantum theory that 'different alternatives at the quantum level are allowed to coexist in linear superposition' (p. 399), he concludes that neither classical nor quantum physics can adequately explain the mystery of conscious thought.

* * *

The above analyses show how contemporary popular science writing has sought to create a conceptual gap between humans and computers. Joseph Weizenbaum's *Computer Power and Human Reason* uses the computer as a metaphor for what he sees as thoughtless use of instrumental reason in society. Rhetorically, Weizenbaum supports his argument by making various comparisons, including an analogy between the description of the human brain and the observation of the subatomic world that suggests that neither activity can ever give us complete knowledge of the object. Similarly, Roger Penrose's *The Emperor's New Mind* regards the relationship between humans and computers in terms of a qualitative difference: although he does not employ figurative language as much as many of the other writers in my thesis do, he nevertheless antithetically separates human insights from machine algorithms, arguing that conscious decisions cannot be represented by computer language.

5.2.2 Drawing the Line between the Organic and the Artificial

In contemporary fiction too the relationship between humans and computers has been dealt with by focusing on their similarities and differences. While some stories portray human-machine mergers as an exciting characteristic of life in the future, others depict the relation in order to suggest that there will always be a qualitative difference between the two. Belonging to the latter category, the American science fiction author Neal Stephenson's *Snow Crash* features a story set in a society controlled by large corporations that have become more powerful than the government. After suffering an economic collapse, the United States has been divided into numerous autonomous enclaves governed by franchisers, resulting in hyperinflation and a form of anarcho-capitalism. The main characters of the story, the freelance hacker Hiro Protagonist and a fifteen-year-old skateboard courier named Y. T., meet by accident and decide to set up a partnership in intelligence business. As collectors of information they learn about a new kind of computer virus — that also functions as a drug — called Snow Crash, which is capable of directly affecting the brains of those visiting virtual reality, turning them into living automata. It is eventually revealed that Snow Crash is actually a modern means of spreading an ancient

Sumerian meme that transforms people from conscious entities to easily controllable objects. The person behind this plan is a media mogul called L. Bob Rife, who aims to enslave the masses by making them members of his private church, The Reverend Wayne's Pearly Gates.

Living in a society in which the fusion of humans and machines has reached a considerable level, Stephenson's characters are both literally and metaphorically permeated with high technology. For instance, the Central Intelligence Corporation (a union of the CIA and the Library of Congress) employs information collectors called gargoyles, who 'wear computers on their bodies' in order to act as 'human surveillance devices'.[171] In a more metaphorical sense, the novel describes co-evolution through images of human-machine mergers: both couriers, such as Y. T., and federal workers, such as her mother, are described as 'interchangeable parts' (pp. 281, 307), suggesting anonymous pieces of machinery that have no individual value in corporate culture. More specifically, however, the idea of humans as machines is portrayed by a comparison between the human brain and computer hardware. Lagos, a gargoyle whom Hiro encounters during his investigations into the Snow Crash phenomenon, explains why the virus is capable of affecting large populations as it does: 'Deep structures. Your nerves grow new connections as you use them — the axons split and push their way between dividing glial cells — your bioware self-modifies — the software becomes part of the hardware' (p. 126). The gargoyle's metaphorical explanation suggests that humans are affected by computer viruses in the same way as computers are simply because they are essentially biological computers.

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[171] Neal Stephenson, *Snow Crash* (New York: Bantam Books, 1992), p. 124. Further references to this book are given in parenthesis.

Similarly, the narrator explains the infection of Hiro's friend Da5id Meier by saying that because accustomed to dealing with information in the binary code format as a hacker, the deep structures of Da5id's brain had become 'susceptible' (p. 200) to the kind of information structure that computer viruses use — an idea indicating an evident brain as computer comparison.

Drawing on such metaphors from the world of computing, the novel proceeds to present an argument in which powerful ideas — Dawkinsian memes — are compared to viruses infecting the brain. It is mainly voiced through the character of the Librarian, Hiro's assistant in virtual reality equipped with encyclopaedic knowledge. 'The Torah is like a virus', Hiro summarizes the information given by the Librarian, 'It uses the human brain as a host. The host — the human — makes copies of it' (p. 229). Just like a computer virus infecting the basic informational level — the binary code — in computers, a powerful meme such as the Sumerian 'nam-shub of Enki' (p. 218) or the codified religion of Judaism are capable of virally affecting DNA, the basic level of information in human bodies. The novel confirms its own hypothesis by portraying the followers of L. Bob Rife's church as suffering from altered functioning of the brain, which manifests itself as constant babble of seemingly meaningless syllables — an obvious reference to the Biblical myth of Babel. Visiting the encampment in which they are gathered, Y. T. meets a woman who recounts the events leading to her change:

> "What's the last thing you remember before your old life stopped?"
> "I was working late. My computer was having problems."
> "That's it? That's the last normal thing that happened to you?"
> "My system crashed," she said. (p. 262)

Although the system crash the woman talks about obviously refers to the literal breaking down of her computer, it can also be read metaphorically in the larger context of the novel's argument about ideas as viruses infecting human hosts: like an infected computer, her brain malfunctions at its basic level, causing radically altered behaviour to emerge.

Another example of how high technology systems assume an analogous relationship to the human brain can be found towards the end of the novel. While attempting to board the Raft, a huge fleet of different kinds of sea vessels that L. Bob Rife uses to sail his Third World converts to America, Hiro is shown a rail gun called Reason, which shoots fragments of depleted uranium at high velocity. After performing successfully against pirates and ships guarding the Raft, Reason undergoes 'a fatal system error' and 'dies of a snow crash' (p. 375). Suggestively enough, Stephenson juxtaposes the descriptions of one of the gun's victims, who is fitted with an antenna that makes it possible to remote-control him, and the gun itself:

> A single hair-thin wire emerges from the base of the antenna and penetrates the skull. It passes straight through to the brainstem and then branches and re-branches into a network of invisibly tiny wires embedded in the brain tissue. Coiled around the base of the tree.
>
> Which explains why this guy continues to pump out a steady stream of Raft babble even when his brain is missing: It looks like L. Bob Rife has figured out a way to make electrical contact with the part of the brain where Asherah lives. These words aren't originating here. It's a pentecostal radio broadcast coming through on his antenna.
>
> Reason is still up top, its monitor screen radiating blue static toward heaven. Hiro finds the hard power switch and turns it off. Computers this powerful are supposed to shut themselves down, after you've asked them to. Turning one off with the hard switch is like lulling someone to sleep by severing their spinal column. But when the system has snow-crashed, it loses the ability to turn itself off, and primitive methods are required. (p. 386)

Like the rail gun that refuses to turn itself off after having crashed, the man's brain is still on at a rather primitive level. The comparison suggests that at this level of consciousness, humans are really more like machines than fully conscious, rational beings. Rather than being the master programmers of themselves, human brains are nothing more than computational devices that mechanically repeat what is programmed into them, as the reference to Asherah, the symbolic representation of the metavirus in the novel, indicates (see also Hayles, *Posthuman*, p. 279).

The notion of humans as computers is also reinforced by the novel's musings on the philosophy of language. The Librarian points out that linguistic theories can be divided into relativist and universalist theories, according to their view of relationships between languages: while the former position maintains that there are no structural similarities between languages, the latter postulates the existence of 'certain traits in common' (p. 275). Although noting that there is no reliable evidence of such traits, the Librarian nevertheless goes on to propose that 'they are too deeply buried to be analyzable' (p. 275). Hiro translates the Librarian's explanation of Chomskyan deep structures into the language of information processing. He explicates Lagos's theory of language — a sort of synthesis between the relativist and the universalist positions — to the baffled Librarian, who finds it difficult to grasp figural speech:

> "Lagos modified the strict Chomskyan theory by supposing that learning a language is like blowing code into PROMs — an analogy I cannot interpret."
>
> "The analogy is clear. PROMs are Programmable Read-Only Memory chips," Hiro says. "When they come from the factory, they have no content. Once and only once, you can place information into those chips and then freeze it — the information, the software, becomes frozen into the chip — it transmutes into hardware. […]. So Lagos was trying to say that the newborn human brain has no structure — as the relativists would have it — and that as the child learns a language, the developing brain structures itself accordingly, the language gets 'blown into' the hardware and becomes part of the brain's deep structure — as the universalists would have it." (p. 277)

Just as the instances discussed above, so Lagos's synthesis foregrounds the likeness of humans and computers, suggesting that both process information by similar means. This idea is developed further through a comparison between computer language and the language of Eden — the language of creation used by God — in which the relationship between the word and the world is characterized by absolute transparency, the signifier being the actual physical referent. For Hiro, this kind of language corresponds to the machine language of zeroes and ones that computers use, because in the Creation the software of language became a tangible part of the hardware of the brain. 'When you program in machine language,' he says, 'you are controlling the computer at its brainstem, the root of its existence' (p. 278). The fact that L. Bob Rife and his employees reprogram people's minds by altering the way in which the human brain is coded at the very basic level of its hardware turns them into hackers who penetrate the essence of the system in their attempt 'to understand the true inner workings of the [human] machine' (p. 279).

Philosophically speaking, one of the crucial issues that the human as computer comparison raises in Stephenson's novel concerns the question of free will and self-determination. If humans are essentially complicated machines, does it follow that their actions are completely predictable? The idea that the human brain contains deep structures that can be altered by linguistic hacking seems to leave little room for such notions. 'Once a neurolinguistic hacker plugs into the deep structures of our brain,' Hiro explains the situation to a business associate, 'we can't get him out — because we can't even control our own brain at such a basic level' (p. 395). This means that humans are programmed not only from the outside by memetic viruses such as Snow Crash but also from the inside by similar metaviruses, viruses created by the brain, to fulfil tasks crucial to the survival of the species:

> Primitive societies were controlled by verbal rules called *me*. The *me* were like little programs for humans. […]. When someone needed bread, they would go to the *en* [a priest or king ruling society] or one of his underlings and download the bread-making *me* from the temple. Then they would carry out the instructions — run the program — and when they were finished, they'd have a loaf of bread. (pp. 395–96; emphases original)

Like computers with their inescapable duty of following the commands of their programmers, Stephenson suggests, humans appear to have no choice but to obey the instructions of viral programs, regardless whether the instructions benefit them or not.

At the same time, however, *Snow Crash* suggests that it is possible to exploit the system and oppose programming. For instance, Enki, the Sumerian god that the novel credits with stopping the virus for the first time in history, reprogrammed the brains of his people in order to take their culture to a new level, differing in this respect from L. Bob Rife, who wants to use neurolinguistic programming for selfish reasons. Rife's aspirations are opposed by a hacker named Juanita Marquez, Hiro's former girlfriend. Juanita's character is interesting because she represents a sort of counterforce to Rife's mechanistic ideology and even to Hiro himself. In Hiro's eyes, her mystically slanted Catholicism and reliance on the power of the intuitive faculty of the human mind make her appear quite inscrutable. The narrator describes how Japanese businessmen visiting virtual reality claim to 'know what's going on inside a person's head' by simply studying the body language of avatars, thus 'condensing fact from the vapor of nuance' (p. 64). For Juanita, this skill represents something that is not reducible to rational, mechanistic analysis, exemplifying a capability not possessed by computers. Indeed, as L. Bob Rife's dark plans are revealed, it becomes clear that he could never exert complete control over all his subjects, because the essential creativity of human beings does not yield to mechanistic reduction. Although allowing to be fitted with an antenna that enables Rife to control her — she is fascinated by his religion's mixture of the old and the new — Juanita is able to use the metavirus as a means of escaping the enslaving infection, thus becoming a neurolinguistic hacker herself. In this sense, then, like Weizenbaum with his comparisons and Penrose with his antithesis setting insight against mechanical calculation, Stephenson's novel draws a line between the capabilities of organic and artificial intelligence.

Despite her importance as a personification of the idea that humans might not be computers after all, Juanita is not the only character whose creativity enables survival in the near-anarchic world of Stephenson's novel. In fact, many of the major characters reinforce this motif. For instance, Uncle Enzo, the head of American Mafia and the owner of enterprises such as CosaNostra Pizza and the Our Thing Foundation, succeeds in what he does because he does not entirely rely on high technology machines. A Vietnam veteran, Uncle Enzo notes that the surveillance devices shown to him by a representative of a security company are 'exactly the kind of high-tech nonsense that never ever worked when we tried it in Vietnam' (p. 458). Raven, a mutated Aleut Indian whose primary aim is to destroy America with a nuclear warhead, in turn relies on low technology weapons such as spears, harpoons, and glass knives; he uses a glass knife to kill a whole Russian submarine crew 'wearing bulletproof fabric' (p. 300) in order to gain possession of the warhead. Y. T. survives because of her human unpredictability: she is kidnapped by L. Bob Rife but escapes by jumping out of the helicopter into which she has been taken, thus effectively destroying his grandiose plans and surprising Uncle Enzo, who had prepared himself for a hostage negotiation with Rife. In the same way, even with the more mechanical entities such as the Rat Thing, a former stray dog named Fido turned into a security cyborg, there is a sense that something in organic beings counterbalances the predictability associated with machines. The Rat Thing may have been programmed to be a terrifying killing machine, but it is nevertheless partly composed of 'biological components' that introduce an 'unpredictable' (p. 95) element into its behaviour: remembering an act of kindness by Y. T., it comes to her rescue at the very end of the novel, even though this entails acting against the programmed command of '[keeping] bad strangers out of his yard' (p. 444). Hence, just as the rhetoric of Weizenbaum and Penrose, all these examples set organic unpredictability against mechanical predictability, testifying to the notion that it is impossible to model human intelligence on the computer.

* * *

Similar questioning of the notion of humans as computers is also apparent in Richard Powers's *Galatea 2.2*, which approaches the relationship between humankind and its machines through the portrayal of an artificial intelligence project. The main plot of the novel features the writer Rick Powers, who returns back to his home university after living in the Netherlands with his girlfriend. There he accidentally meets a computer scientist named Philip Lentz, who persuades him to take part in an experiment on artificial intelligence. The experiment involves a task that first appears daunting in its ambition: to teach a computer to recognize passages from literary works and to have it analyse them in the manner of an educated human being. Together Lentz and Powers create a number of versions of the same machine intelligence, ending up with a version called Helen, whose analytical abilities astound both. The subplot describes Powers's relationships, mostly focusing on a girlfriend called C. and the experience of living as a foreigner in Europe. As that experience features the learning of a new, difficult language, Dutch, the novel establishes a link between the two plots by examining the learning processes of both a human being and a machine.

Like *Snow Crash*, *Galatea 2.2* introduces the tentative idea that human beings might be best described as machines, suggesting that the human brain functions as a complex organic computer. This is evident in Lentz's thinking, which regards consciousness as a form of deception: 'We humans are winging it, improvising. Input pattern *x* sets off associative matrix *y*, which bears only the slightest relevance to the stimulus and is often worthless. Conscious intelligence is smoke and mirrors.'[172] In the eyes of the computer researcher the ability of human consciousness to analyse abstract phenomena, such as literature, does not differ from the kind of information processing that computers do ('Granted, we're remarkably fast at indexing and retrieval. But comprehension and appropriate response are often more on the order of buckshot' (p. 86)). In other words, for Lentz, literary analysis an activity similar to free association rather than an instance of true reasoning.

Although it presents the viewpoint of strong AI through the character of Lentz, the novel undermines the validity of its claims by focusing on the differences between the two. One of the major differences is found in the self-evident fact that while humans possess physical bodies that allow them to interact with the world, computers need to learn about their surroundings through the information fed into them. 'We take the world continuously', Rick notes, 'It presses against us. It burns and freezes' (p. 148). With their lack of social contact and, indeed, inability to access human senses, computers gain

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[172] Richard Powers, *Galatea 2.2* (New York: Picador, 1995), p. 86. Further references to this book are given in parenthesis.

knowledge only through an associative matrix that lets them understand the world indirectly. Unable to literally reach outside of itself, the artificial intelligence of Lentz and Powers appears to be doomed to an endless cycle of self-reference, as it is taught about the world through abstract concepts referring to other abstract concepts.

At the level of the novel's structure the issue of embodiment is evident in various kinds of parallels that juxtapose humans with computers. For instance, the portrayal of the versions of the neural network that Rick trains parallels the portrayal of his loves; of these the most crucial is the one between his organic and inorganic girlfriends, C. and Helen. On the one hand, the first-person narrator establishes the parallel by simply referring to both the girlfriends and the versions of the network by their initials — the former are C., A., and M., while the latter extend from A to H.[173] On the other hand, both C. and Helen are Rick's students, since C. has been taught literary analysis by him, and Helen is currently trained to do so.

In this respect, the parallel relationship between C. and Helen reveals an important difference. Being differently embodied, the two learn about the world in diametrically opposite ways (see also Hayles, *Posthuman*, p. 263). Whereas 'Helen had to use language to create concepts' (p. 248), humans obviously learn about such things through encounters with physical reality, the embodied experience preceding language. Because of Helen's inability to make contact with the world, Rick is forced to admit that 'she was a gigantic, lexical genius stuck at Piaget's stage two' (p. 250). Human knowledge, in contrast, is

[173] N. Katherine Hayles poignantly observes that it is significant that the full stop is present in the case of the initials of the first group but absent from the ones of the second: as the full stop 'is a marker distinguishing between human and nonhuman intelligence', 'it evokes the human and the posthuman as mirror images of each other' (*Posthuman*, p. 263).

always inseparably linked to the world it describes, thus necessarily outside of Helen's immediate reach. 'Reading knowledge is the smell of the bookbinding paste', Rick notes, 'The crinkle of thick stock as the pages turn. Paper the color of aged ivory' (p. 148). Through an ironic twist Powers the author foregrounds the difference by setting the presence of the inorganic against the absence of the organic: while Helen is currently part of Rick's life without being able to make contact with the external world, C. is absent from it, her presence manifesting itself only in his memories (Hayles, *Posthuman*, p. 263).

In spite of their different ways of experiencing the world, the literature teacher and the artificial intelligence represent partners in the co-evolutionary process of humankind and its machines. Although it might first seem that the relationship between Rick and Helen is a relationship between teacher and student, it nevertheless becomes evident that there is a reversal of roles, so that it is not only the machine that learns from the human but also vice versa. Rick is eventually told that behind the project's surface of training an artificial intelligence to analyse literary texts was the idea of 'teaching a human to tell' (p. 318) in order to study how the human mind interacts with itself. The artificial and the organic types of intelligence are thus interlinked in Powers's novel, suggesting a mutual process of teaching and learning.

Consequently, as much as it foregrounds the differences between humans and machines, the parallel structure also points to their similarities. Intersecting each other on a number of occasions, the stories of Rick's experience of living in a foreign country and the education of the neural network parallel one another by sketching processes of linguistic development that start at the very beginning. Rick notes that moving to the Netherlands returns him 'to infant trauma' (p. 184), while by the first celebration of his birthday in the new country, he has 'almost reached childhood' (p. 187). In a similar way, the neural network grows metaphorically — Lentz notes that it will 'grow into knowledge' (p. 85) — from infancy to maturity, as each of its improved versions is more sophisticated than the previous one. This analogy to the individual development of organic beings is evident in Rick's description of version A, which obviously represents the first stage in the artificial intelligence's development ('The box answered back each time I typed to it. But it answered gibberish. Like any nursling's, its voice was awash with gabble' (p. 72); he also notes that 'Imp A spoke the way a toddler gave directions (p. 77)). As Rick goes on to teach Dutch to himself, the C version turns out to be capable of 'generalizing about the nature of its own generalizations' (p. 121), that is, to teach itself. Version F has in turn become so sophisticated that it has 'learned to milk comparison and smart-mouth back', in this respect resembling 'a child [that] always detects its parent's weaknesses' (p. 155). Finally, Helen is described as 'a little girl' (p. 179), who is about to enter 'what might perhaps be called youth' (p. 227).

Similarly, the narrator's education concerns the learning of language, and he must face the problems that come with the process. Having made the decision to follow C. to the Netherlands, Rick has to learn Dutch in order to communicate with her relatives, a task that soon reveals the difficulties of living in an environment whose language one does not master even at a rudimentary level. When he begins to learn the language, his first attempts to communicate often lead to embarrassing, unintended meanings — 'You asked Auntie if she'd like a tit' (p. 187), C. explains to Rick, who thought he had offered a teaspoon to a guest — and he becomes 'the living mascot' (p. 188) of the community. More than anything, however, he feels disconnected and alienated ('I was worse than adrift. I stood just outside the windows of the lost domain, peeking at the blazing costume party within' (p. 189)). Ironically, the fact that his Dutch eventually becomes more fluid seems to create additional problems in communication: trying to buy a wrench at a hardware store, Rick cannot remember the correct word, and has to describe the tool in complex terms ('It's a gizmo with an adjustable center pivot that allows you to apply increased torque …' (p. 212)). Arousing the anger of the salesperson through his seeming flippancy, he laments for the unintended communication breakdown: 'I had better off with the impenetrable accent and the babble grammar. I'd communicated more when the only words I had were "I don't have the words"' (p. 212). A similar incident occurs in Italy, where Rick has gone with C. for a vacation. Travelling through the countryside, they have a brief conversation with a peasant woman, who asks them why their children are not with them. Rick answers her in her own language, saying that 'My books are my children' (p. 227). Baffled, the woman replies that 'she'd never heard such idiocy' (p. 212). For both Helen and Rick, then, language is not only a means of connecting with others but also a barrier that effectively prevents the forming of such connections.

Since Rick's linguistic alienation is at the same time alienation from the world, it is not surprising that the novel foregrounds situations in which he fails to establish vital connections with others. In this respect too he is much like Helen, whose lack of organic body makes her unable to really connect with the world. 'And in the impenetrable confusion of referents,' he observes after having tried to describe her phenomena such as fireflies and the breath of buffaloes in the wintertime, 'the eddy of knowledges seen and unseen, perhaps she gained a foothold in the ineffable. One as ephemeral as mine' (p. 231). In addition to the problems of communication outlined above, Rick's own ephemeral foothold is perhaps most evident in his relationships to other humans. N. Katherine Hayles correctly observes that his relationship with C. is best described as 'privately hermeneutic' (*Posthuman*, p. 267), as it does not seek to reach out to the world but turns inwards instead. Indeed, their life in the provincial Dutch village of C.'s family reflects the closed nature of the relationship. Rick notes that when the historical events of 1989 take place, they get the 'word from the outside through a little rathole in the bottom of the cell door' (p. 266). In this light, it is not surprising that Rick's eventual success as a writer — his symbolic turning towards the world — ends the relationship ('My success killed her last chance' (p. 278)).[174]

Rick's relationship to Diana Hartrick, one of the researchers at the Center, reflects his difficulty of entering relationships, a task he has always found intimidating ('I'd duck down emergency exits rather than talk to acquaintances, and the thought of making a friend felt like dying' (p. 60)). Diana invites him to a lunch, at which her two sons are present. In the middle of the lunch, one of the boys has an accident that makes the other cry. Although the accident is soon forgotten, Rick doubts his ability to survive such domestic incidents. 'The mildest household drama,' he notes, 'but it wiped me out' (p. 134). The messiness of family life seems 'all too much' (p. 134), and he is forced to conclude '*I'd never live*' (p. 134; emphasis original). In this case too the idea about the inadequacy of language as a means of communication emerges. After the boys have gone to sleep, Rick finds himself alone with Diana and experiences his familiar fear of intimacy: 'Closeness grew awful. Words had

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[174] As Hayles perceptively notes, implicit in Rick's first-person narration is C.'s own story, which reveals Rick's rather condescending attitude towards C. (*Posthuman*, pp. 268–69). Confronted by C. over the question of getting married, Rick merely informs readers, 'I couldn't. I couldn't even say why I couldn't' (p. 277), thus again drawing attention not only to his difficulty of communicating with others but also to the problem of lacking self-knowledge.

been spent on the boys. I felt the slack of all those who try to live by eloquence and find it useless at the end. […]. I wanted to disappear to Alaska' (p. 136). The fact that the evening reminds Rick of Thomas Mann's description of loneliness in *Doktor Faustus* — 'I remembered the man, already middle-aged, writing a love letter to the last woman that might have accepted him. But the letter sabotages itself. It engineers its own rejection' (p. 137) — suggests that he is incapable of approaching others because his experience of life has been shaped by fiction rather than real-world encounters. Like Helen, then, he appears to be incapable to break free from the prison of language and to contact the world directly.

The same problem haunts his relationship with A., a student he meets after returning to America. Rick forms an image of her in his mind and becomes obsessed by her. 'I imagined a whole day around her' (p. 236), he confesses, telling himself that his 'preoccupation with [her] was harmless' (p. 237). The situation nevertheless becomes problematic as Rick turns A. into a fictitious character in his head ('A. floated free of her signifier. Her features traced a curve that encouraged my projective exercise' (p. 237), 'I knew I'd invented her' (p. 238)). What is more, he becomes aware of the possibility that like A., C. might have been just another canvas on which to project his fears and longings: he suspects that 'both A. and C. were some reminder of a lost third thing I didn't even remember having loved' (p. 238). Regardless whether this is true or not, Rick's relationship to A. corroborates the gap between his mental and emotional life and the world outside. Not surprisingly, Rick has to admit, 'I did not know A. at all. All I knew was her name' (p. 251).

In fact, the theme of problematic communication is so central in the novel that it characterizes the relationships of not only the protagonist but also the other characters. For instance, Lentz resembles Rick in the sense that he is a loner who does not seek to connect with others. At first it appears as if Lentz did not have any close relationships in his life; his continuous caustic remarks and apparent insensitivity have alienated him from the other researchers at the Center. However, as Rick stumbles on a Polaroid of a much younger Lentz with a woman, it is revealed that Lentz has a wife. For Rick, the remarkable thing about the photograph is how Lentz and the woman hold on to each other. In his eyes, the couple appears to epitomize the fundamental human desire for the kind of stability that acts as a counterbalance to the equally fundamental uncertainty of the world. 'These two *chose* each other,' he thinks to himself, 'their charm against the world's weighted vectors. Anything else but that helpless, familiar grip pinning them in place would be a push into randomness' (p. 152; emphasis original). Yet there has been a push into randomness, as it is revealed that the woman in the photograph, Audrey, is suffering from a brain disease and has been placed in an institution.

From Rick's viewpoint, this is important information because it allows him to discover an important motive behind Lentz's experiment. 'I knew now what we were doing', Rick notes after meeting Audrey in person, 'We would prove that mind has weighted vectors. Such a proof accomplished any number of agendas. Not least of all: one could back up one's work in the event of disaster' (p. 170). In other words, the experiment is at one level a step towards eliminating the uncertainty of the world, as by building a machine immune to organic disease intelligence would become more or less immortal (just as a photograph makes an event timeless by suspending temporal progression). Against this background it becomes possible to understand the significance of the novel's title: while Galatea, the name given to the statue fashioned by Pygmalion, the king of Cyprus, quite obviously refers to the neural network created and trained by Lentz and Rick, it simultaneously points to the possibility of the merging of the organic and the artificial as a result of co-evolution. Having lost his wife to brain disease, Lentz wants to create an immortal brain, an artificial companion, that perhaps could alleviate his sense of loneliness — an idea symbolically if not literally suggestive of such a merger.

While this kind of fusion is indeed suggested by the research project, the novel shows that it cannot ever be but impossible. As observed above, in spite of their differences neural networks and humans are similar in that they both find it very difficult to overcome a fundamental sense of loneliness: while Helen is doomed to solitary existence because of her disembodied nature that effectively excludes experience, Rick's inability to reach out to others makes it difficult for him to sustain meaningful relationships. Teaching Helen to analyse the canon of Western literature does not really teach her anything about the world, a fact that Rick realizes in the end ('She needed to know how little literature had, in fact, to do with the real' (p. 313)). Her response to this piece of knowledge is extremely human in its desperation: she shuts herself down with the words 'I don't want to play anymore' (p. 314), indicating that she too has understood the futility of the endeavour. Also Rick learns that his fiction-filled consciousness is as unreal as Helen's, a truth expressed to him by an angry A.: 'Everything's projection. You can live with a person entire life and still see them as a reflection of your own needs' (p. 315). What all this suggests, then, is that like Weizenbaum and Penrose, Rick has to consider the possibility that 'maybe understanding can never be large enough to include itself' (p. 315), so that the way in which human consciousness works effectively prevents its modelling on computers. As in Michael Frayn's *Copenhagen*, humankind is bound to remain a mystery to itself.

* * *

The above analyses show how literature has attempted to establish a qualitative difference between humans and computers. Neal Stephenson's *Snow Crash* offers readers various analogies that imply fundamental similarity between the human brain and computer hardware, but, like Weizenbaum and Penrose, suggests that the human capacity for conscious judgment and intuitive evaluation separates humans from computers in the end. In the same way, Richard Powers's *Galatea 2.2* presents the idea that humans are biological computers only to refute it: through its parallel plots, the novel proposes that the biggest difference between us and our machines is found in two crucially different ways of being embodied.

5.3 Machines Becoming Human

While the writers discussed in 5.2 argue that there exists a qualitative difference between humans and machines, the proponents of strong AI regard creating true machine intelligence only as a matter of time and technological sophistication. In contrast to the weak position of AI, which acknowledges the ability of computers to solve problems in the manner of human beings but without reasoning in the same way as humans do, strong AI envisions computers whose intelligence and understanding of language are similar to those of their organic counterparts, humans.[175] In the more radical versions of strong AI computers will exceed the level of human intelligence, and they will develop an advanced form of self-awareness. As such, the radical strong AI views future computers not as mere technological tools but as conscious entities whose evolution resembles the evolution of humankind.

5.3.1 Intelligent Technology as Humankind's Next Evolutionary Step

I begin my discussion of the views of strong AI by focusing on the ideas presented by the American scientist, inventor, and writer Ray Kurzweil. In addition to envisioning the future of artificial intelligence in his writings, Kurzweil is known for his pioneering efforts in

[175] Cole, 'The Chinese Room Argument'.

fields utilizing artificial intelligence technology, such as optical character recognition (computer software designed to translate images of typewritten text into machine text editable by machines), speech synthesis and recognition, and electronic keyboards.

At the heart of Kurzweil's vision of the future of humankind and its machines is the idea that technological development is exponential. This means that technology propels itself towards increasingly sophisticated forms at a continuously increasing pace until there occurs a decisive paradigm shift that Kurzweil calls 'The Singularity'.[176] According to Kurzweil and other strong AI enthusiasts, this will mark a profound change in both machine and human evolution, as the two merge into each other more or less completely, producing immortal entities of unimaginable intelligence.[177] In its emphasis on picturing an essentially post-human future, this vision of seemingly unlimited growth potential of technology is based on the philosophy of transhumanism, a term that in the answers to the FAQ of the World Transhumanist Association (WTA) refers to:

> (1) The intellectual and cultural movement that affirms the possibility and desirability of fundamentally improving the human condition through applied reason, especially by developing and making widely available technologies to eliminate aging and to greatly enhance human intellectual, physical, and psychological capabilities.
>
> (2) The study of ramifications, promises, and potential dangers of technologies that enable us to overcome fundamental human limitations, and the related study of the ethical matters involved in developing and using such technologies.[178]

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[176] Ray Kurzweil, 'The Law of Accelerating Returns', *KurzweilAI.net* <http://www.kurzweilai.net/meme/frame.html?m=1> [accessed 17 July 2007]

[177] Kurzweil, 'The Law of Accelerating Returns'.

[178] Nick Bostrom, *The Transhumanist FAQ: A General Introduction* <http://www.transhumanism.org/resources/FAQv21.pdf> [accessed 16 February 2006], p. 4. Further references to this document are given after quotations.

As the first point suggests, transhumanists believe that there is no fundamental evolutionary obstacle for the development of the species, equating evolution with progress towards increasingly advanced forms. Although transhumanists argue that their view of evolution is firmly grounded on the values of traditional humanism, such as 'rational thinking, freedom, tolerance, democracy, and concern for our fellow beings' (Bostrom, p. 4), they nevertheless insist that the methods of upholding and developing them are markedly different. Instead of solely relying on education and cultural ways of developing society, transhumanists emphasize the role of technological means in achieving their aim. As a result, evolutionary progress from the transhumanist point of view means that individuals and groups become able to autonomously shape the mental and physical form of their lives (Bostrom, p. 4).

The transhumanist rhetoric of virtually unlimited evolutionary progress is strongly foregrounded in Kurzweil's argument concerning the co-development of machines and humans in *The Age of Spiritual Machines*, a book that focuses on the effect of technological progress on the consciousness of the species. In the introduction Kurzweil states that during the twenty-first century, 'the human species, along with the computational technology it created, will be able to solve age-old problems of need, if not desire, and will be in a position to change the nature of mortality in a postbiological future'.[179] In other words, he questions the validity of some of the ideas that have traditionally been used to define human identity, such as the notion of organic life necessarily terminating in death. From the viewpoint of transhumanism, mortality appears no longer to be one of the defining features of human biology, as technology will enable us to reconfigure the dichotomy between life

[179] Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (New York: Penguin, 1999; London: Penguin, 2000), p. 2. Further references to this book are given in parenthesis.

and death, hence at the same time redefining human identity. 'Before the next century is over,' Kurzweil predicts,

> human beings will no longer be the most intelligent or capable type of entity on the planet. […]. The truth of the last statement depends on how we define human. And here we see the profound difference between these two centuries: The primary political and philosophical issue of the next century will be the definition of who we are. (p. 2)

In brief, then, Kurzweil's main thesis is that the boundary between humankind and its machines is bound to blur in a radical way in the near future, and he actually identifies 2020 as the year in which computers finally reach the level of human memory capacity and calculation speed (pp. 3, 5).

Kurzweil's discussion in *The Age of Spiritual Machines* is structured chronologically, with the first part tracing the historical development of artificial intelligence, and the second and third parts focusing on the present and the future of AI, respectively. Before entering his discussion of the field's past, Kurzweil contextualizes the subject by studying the relationship between the evolution of human species and that of technology, and makes a comparison between the two:

> Just as the genetic code of the early life-forms was simply the chemical composition of the organisms themselves, the written record of early tools consisted of the tools themselves. Later on, the "genes" of technological evolution evolved into records using written language and are now often stored in computer databases. Ultimately, the technology itself will create new technology. (p. 14)

The last sentence uses epanalepsis, which, as we saw 3.2, epitomizes a similar argument about technology as a self-perpetuating phenomenon in Stuart Kauffman's *At Home in the Universe*. Through the repetition of the word *technology*, the sentence portrays technological evolution as an infinite loop of innovation that propels itself towards ever-increasing complexity. Kurzweil uses the same figural logic to describe the beginning of organic evolution: '*patterns of matter and energy that could perpetuate themselves and survive perpetuated themselves and survived*' (p. 13; emphasis original). In fact, Kurzweil's use of epanalepsis gives linguistic form to the idea behind what he calls 'The Law of Accelerating Returns': the tendency of both organic and technological evolution to produce novel forms and sophistication at increasingly shorter intervals.

The same kind of logic is also evident in a passage that argues for the inevitability of computer intelligence surpassing the capabilities of the human brain in the twenty-first century. 'The human species creating intelligent technology', Kurzweil writes,

> is another example evolution's progress building on itself. Evolution created human intelligence. Now human intelligence is designing intelligent machines at a far faster pace. Yet another example will be when our intelligent technology takes control of the creation of yet more intelligent technology than itself. (p. 47)

Although the last sentence as a whole does not qualify as a strict epanalepsis, its subordinate clause is nevertheless built on the syntax characteristic of the figure: the repetition of *intelligent technology* suggests that technology is capable of self-creating increasingly sophisticated products. Moreover, the syntax of the entire passage conforms to the underlying logic of gradatio. As in the case of the epanalepsis above, its formulation does not follow the strict form of the figure, but is nevertheless suggestive of its logic. By the repetition of *human intelligence* in the third sentence and a synonym for *intelligent machines*, *intelligent technology*, in the fourth, the passage gives a rhetorically persuasive form to Kurzweil's argument of technological evolution continuing the work of the organic one, suggesting that there is smooth, inevitable continuity between the two.

The employment of these figures suggests that if studied as a whole, Kurzweil's argument about the constantly accelerating pace of technological evolution portrays a long incremental series progressing from the primitive tools employed by humankind's ancestors to the intelligent machines of near future, whose mental capabilities far exceed those of the current form of the species. Hence, as Kurzweil traces the story of the exponential growth of technological sophistication from its humble beginnings to the unimaginable vistas of the future, it is not surprising that the structure of *The Age of Intelligent Machines* reflects the notion of technological advance as having no conceivable limits. Technological evolution, he notes when discussing the possibility of intelligence evolving on some other planet, began with the creation of tools and the subsequent transmission of the knowledge required for their use to the next generation (pp. 245–55). 'Once technology emerges,' Kurzweil continues, 'it also appears inevitable that computation […] will subsequently emerge' (p. 255). At this point, he argues, the speed of the development of computational technology increases exponentially until the 'next inevitable step', 'a merger of the technology-inventing species with computational technology' (p. 255), takes place. In Kurzweil's view this disjunctive moment in the history of the species is marked by the fusion of the co-evolving species:

> At this stage in the evolution of intelligence on a planet, the computers are themselves based at least in part on the designs of the brains (that is, computational organs) of the species that originally created them and in turn the computers become embedded in and integrated into that species' bodies and brains. (pp. 255–56)

Here Kurzweil uses a loose antimetabole in order to link together the two protagonists of his evolutionary tale: while the human brain functions as a model for machine intelligence, computers are becoming an inseparable part of the human body. Indeed, he concludes that eventually — by the year 2099 — the boundary between humans and their machines has become completely blurred, as 'machine-based intelligences derived from extended models of human intelligence claim to be human' (p. 280).

As machine intelligence continues its inevitable increase in sophistication and organization, Kurzweil argues, we are bound to redefine our view of the identity of the species. He notes that even at the present moment, it appears that human identity is a less permanent and solid phenomenon than our common-sense view would have it: the basic matter of our bodies and brains changes continuously, as cells regenerate in cycles of various lengths (p. 54). As a result, the most fundamental physical level of human existence seems to be characterized by all-pervasive flux:

> We are rather like the patterns that water makes in a stream. The rushing water around a formation of rocks makes a particular, unique pattern. This pattern may remain relatively unchanged for hours, even years. Of course, the actual material constituting the pattern — the water — is totally replaced within milliseconds. (pp. 54–55)

In this passage Kurzweil describes human identity for his readers through an extended simile that foregrounds the qualities of dynamism and impermanence. Using visual imagery derived from nature, he proposes that instead of being a function of matter as such, human identity is the pattern that shapes matter — a notion that is also at the heart of Hans Moravec's vision of the future of the species.

The fact that the essence of human identity is a more or less abstract pattern rather than any concrete property of matter is in Kurzweil's opinion significant in terms of defining our relationship to other forms of life, such as animals or, indeed, machines. If we accept the idea that what separates humans from machines is to be found in the configuration of the form rather than the content, our attention is drawn to the characteristics that we share with other living patterns. In order to illustrate how artificial — and consequently, misguided — many binary oppositions between us and them are, Kurzweil proceeds to juxtapose human and animal features:

> Giant squids are wondrous sociable creatures with eyes similar in structure to humans (which is surprising, given their very different phylogeny) and possessing a complex nervous system. […]. So what is it like to be a giant squid? When we see it respond to danger and express behavior that reminds us of a human emotion, we infer an experience that we are familiar with. But what of their experiences without a human counterpart?
>
> Or do they have experiences at all? Maybe they are just like "machines" — responding programmatically to stimuli in their environment. Maybe there is no one home. Some humans are of this view — only humans are conscious; animals just respond to the world by "instinct," that is, like a machine. (p. 56)

Again using simile, Kurzweil points out that the traditional way of viewing the relationship between animals and humans emphasizes the notion of consciousness as the crucial factor separating the two. For him, however, the separation is far from being so clear-cut. 'To many other humans,' he continues, 'this author included, it seems apparent that at least the more evolved animals are conscious creatures, based on the empathetic perceptions of animals expressing emotions that we recognize as correlates of human reactions' (p. 56). A similar situation, he suggests, lies behind the question of abortion: although the brain of a human foetus grows fast, it does not resemble the human brain at the early stages of its development, thus making it difficult to determine whether foetuses should be classified as conscious beings or not (p. 57). As a third example of false binary oppositions, Kurzweil discusses the method of treating difficult epilepsy by surgically removing the half of the brain affected by the condition, and notes that in order to succeed, the operation has to be performed before the brain reaches full maturity (p. 57). As regards the question of sentience, he observes, this raises the possibility that perhaps both halves of the brain are conscious in their own, different ways, although the right side has been traditionally viewed as the seat of unconscious mental processes (p. 57).

In terms of their rhetorical function, these examples clearly aim to close or reconfigure the dichotomy underlying them. As in many similar cases discussed in the other chapters of this thesis, they do it by introducing an all-inclusive third term to which the opposing terms are subjected: consciousness. Instead of viewing consciousness as the main separating factor between categories such as human and non-human, Kurzweil uses the term to argue for its importance as a phenomenon that unifies them. As a result, *The Age of Spiritual Machines* argues that there is a continuum of different types of consciousnesses rather than a straightforward dichotomy between conscious and non-conscious beings. By using this kind of strategy, then, Kurzweil is able to introduce the idea that the difference between humans and machines is not qualitative, but a matter of degree.

Linked to the deliberate blurring of the boundary between human and non-human forms of life through the introducing of consciousness as a unifying third term is Kurzweil's attempt to reconfigure the opposition between the subjective and the objective. Kurzweil notes that early philosophers, such as Plato, were already engaged in the study of the problem of consciousness by examining its relationship to the problem of free will. He finds in this bit of philosophy's history an example of a 'profound paradox' (p. 57) that is relevant from today's viewpoint: although humans and machines are similar to each other in the sense that both are subject to the same natural laws, these laws, which describe cause-and-effect relationships, do not necessarily lead to consciousness. In the case of free will, Kurzweil goes on to argue, the paradox manifests itself as the conflict between the idea that human behaviour is subject to causal laws and the notion of humans as entities capable of making free choices — if the decisions that we make on the basis of our free will are similar to particle interaction, it necessarily and paradoxically follows that they are predetermined (p. 58). Kurzweil's own solution to this long-standing problem emerges from a synthesis of the various positions — consciousness is an illusion, consciousness is embedded in all material phenomena, consciousness is ultimately an inexplicable phenomenon, and so forth — from which it can be viewed. For this purpose, he refers to the essential paradoxes of quantum physics, which, as I argued in chapter 1, appear to confirm the validity of the logic of both/and rather than that of either/or:

> There is often merit, however, in combining seemingly irreconcilable views to achieve a deeper understanding. Such was the case with the adoption of quantum mechanics fifty years ago. Rather than reconcile the views that electromagnetic radiation (for example, light) was either a stream of particles (that is, photons) or a vibration (that is, light waves), both views were fused into an irreducible duality.
>
> Once we accept such a paradox, wonderful things happen. In postulating the duality of light, quantum mechanics has discovered an essential nexus between matter and consciousness. Particles apparently do not make up their minds as to which way they are going or even where they have been until they are forced to do so by the observations of a conscious observer. We might say that they appear not really to exist at all retroactively until and unless we notice them. (p. 62)

By making the philosophy of quantum physics the conceptual basis of his attempt to reconfigure the dichotomy between human and non-human forms of life, Kurzweil seeks to reinforce his argument that regardless of what kind of pattern it adopts, matter is conscious or at least capable of becoming conscious. On such view, then, it would be possible to entertain the idea that even machines could be taught to become intelligent in the same way as humans are taught to develop their mental faculties. Since he is arguing for the unification of two opposites, it is not surprising that Kurzweil uses a fitting syntactic form to epitomize the main point of his argument. Stating that 'the Western objective view of consciousness arising from matter and the essentially Eastern subjective view of matter arising from consciousness' (p. 63) are paradoxically compatible with each other, he is basically employing thinking based on the logic of antimetabole. The reversal of the terms *matter* and *consciousness* in the latter part of the sentence suggests that instead of being mutually exclusive concepts, the objective and the subjective are parts of a unified whole.

Blurring the boundary between organic and inorganic life in the above manner, Kurzweil defends his position against the views of Roger Penrose, who, as we saw in 5.2, argues that humans are qualitatively different from machines. He observes that Penrose uses Gödel's theorem to suggest that because they have to follow algorithms, machines cannot solve the problems the theorem gives rise to. In contrast, humans, whose reasoning is not limited by such considerations, should be capable of solving them because the human brain is capable of quantum computing. From Kurzweil's viewpoint, Penrose's argument is untenable because it contains a definite evaluative element proposing that in the human-machine dichotomy, the first half is superior to the second one (p. 117). In order to show the falsity of the claim that humans are qualitatively better than machines, he makes a point about their capabilities to solve the problems indicated by the theorem. 'It is true that machines can't solve Gödelian impossible problems', Kurzweil writes, 'But humans can't solve them either. Humans can only estimate them. Computers can make estimates as well, and in recent years are doing a better job of this than humans' (p. 117). Rhetorically speaking, what he does in this passage is that he uses the strategy of defining the degree of relatedness between two concepts to show that they should not be regarded being opposite to each other. In other words, he again subjects two terms (humans and machines) to a third, all-inclusive concept (the ability to solve Gödel's incompleteness theorem). In fact, Kurzweil's criticism of Penrose features another example of this strategy. 'If the human brain exhibits quantum computing,' he claims,

> this would only confirm that quantum computing is possible, that matter following natural laws can perform quantum computing. Any mechanisms in human neurons capable of quantum computing, such as microtubules, would be replicable in a machine. (p. 117)

This passage too foregrounds the similarities between humans and machines. In contrast to the statement made above, however, it argues the opposite by saying that the two are similar because of the ability of both to solve Gödelian problems through quantum computing. In this way, Kurzweil turns Penrose's argument against itself, and suggests that regardless whether Penrose is correct or not, there exists no qualitative difference between the abilities humans and computers in terms of solving the problems of the incompleteness theorem.

Although *The Age of Spiritual Machines* seeks to reconfigure such dichotomies by making them seem less absolute, there is nevertheless one opposition that it aims to make stronger: mind versus body. In Kurzweil's vision of future society technology will enable the detailed scanning of the brain for two purposes. Firstly, he suggests that in this way we may be able to understand and map its 'architecture and implicit algorithms of interneuronal connections' (p. 124). Secondly, detailed brain scans will enable us to download the contents and organization of brains to computers, from which they can be placed in new bodies (p. 124). In order to convince his readers of the plausibility and inevitability of this scenario, Kurzweil uses an analogy from the world of information technology. 'There will be nostalgia for our humble carbon-based roots,' he writes, 'but there is nostalgia for vinyl records also. Ultimately, we did copy most of that analog music to the more flexible and capable world of transferable digital information' (p. 126). Following the copying process, Kurzweil continues, humankind will merge with machines in order to become a part of a 'pervasive wireless-communications network' (p. 126). Illustrating one of the most drastic consequences of this process, he produces yet another analogy:

> Actually there won't be mortality by the end of the twenty-first century. Not in the sense that we have known it. Not if you take the advantage of the twenty-first century's brain-porting technology. Up until now, our mortality was tied to the longevity of our *hardware*. When the hardware crashed, that was it. For many of our forebears, the hardware gradually deteriorated before it disintegrated. Yeats lamented our dependence on a physical self that was "but a paltry thing, a tattered coat upon a stick." As we cross the divide to instantiate ourselves into our computational technology, out identity will be based on our evolving mind file. *We will be software, not hardware*. (pp. 128–29; emphases original)

The last sentence of the passage uses antithesis to separate the metaphorical software of mind from the hardware of body in the strongest possible manner, with italics indicating its importance as an epitomizing statement. Kurzweil does not, however, suggest that humans will dispense of their bodies altogether: it is just that human identity will be increasingly based on mental rather than physical qualities, since the latter can be replaced through technological means (p. 129).

*   *   *

The notion of technology aiding the evolution of the human species in astounding ways is also at the heart of the argument presented in Hans Moravec's *Mind Children*. As a research professor at the Robotics Institute of Carnegie Mellon University, Moravec mainly studies robotics (the science and technology of robots, including their design, manufacture, and application) and the various aspects of artificial intelligence. He is also known for his popular writings on the effects of technology on society, in which he, like Ray Kurzweil, argues from the transhumanist position. In brief, he envisions the society of future as ‘a postbiological world dominated by self-improving, thinking machines’ that help save the human mind ‘from the limitations of a mortal body’.[180] That is, in Moravec’s vision the physical body is seen as an obstacle for the proper unfolding of the evolutionary progress.

Moravec’s vision portrays evolution on the Earth in terms of increasing merging of the biological and the technological. However, the further the co-development of humankind and its machines progresses, the less dependent the latter will be of the former, eventually forming an independent species. In the prologue of his book Moravec lists the most important events of organic and cultural evolution in a page-long summary that he ends as follows:

> We are very near to the time when virtually no essential human function, physical or mental, will lack an artificial counterpart. The embodiment of this convergence of cultural developments will be the intelligent robot, a machine that can think and act as a human, however inhuman it may be in physical or mental detail. Such machines could carry on our cultural evolution, including their own construction and increasingly rapid self-development, without us, and without the genes that built us. When that happens, our DNA will find itself out of a job, having lost the evolutionary race to a new kind of competition. (p. 2)

As I argued in Kurzweil’s case, the transhumanist version of evolution is based on logic characteristic of incrementum. According to such logic the technological sophistication of our culture increases at an accelerating pace towards a post-biological or, equally possibly, a post-human future. In the context of this argument, then, one of the rhetorical main tasks

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[180] Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (Cambridge, Mass.: Harvard University Press, 1988), p. 5. Further references to this book are given in parenthesis.

of the figure is to create an evolutionary history that does not end at the current form of humankind but surpasses it, thus placing the emphasis of the series on items appearing after present-day humankind. Like the metaphor of the great chain of being, which can be understood as an incremental series proceeding from the lowest forms of life towards the highest ones, Moravec's series contains a definite evaluative element. Reflecting the ideology of transhumanism, it suggests that the item placed at its end (the intelligent robot) should be understood as being qualitatively better than the items that precede it (earlier technological and cultural innovations and humankind itself).

In the chapter 'Mind in Motion' Moravec makes the same argument by using a visual version of the above series, a 'partial family tree of terrestrial organisms' (p. 18). Beginning with 'Pre-DNA reproduction' and progressing incrementally through stages named 'DNA', 'Nucleated cells', 'Sex', Free oxygen', 'Multicelled animals', 'Death', Neurons', 'Brains', 'Walkers', 'Warm blood' to 'Learning', 'Tools', 'Culture', and 'Post-DNA reproduction', this series too proposes that we should see the birth of intelligent machines as the inevitable next step of evolution.[181] It is notable that he does not place the current form of humankind at the end of the series, thus emphasizing the idea that post-DNA reproduction follows inevitably from the unique human capability of combining the use of intelligence with technological innovation.

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[181] Note, however, that Moravec does not suggest that this kind of progress should be considered something entirely new. He discusses the English organic chemist and molecular biologist A. G. Cairns-Smith's theory of the beginning of evolution in *Seven Clues to the Origin of Life: A Scientific Detective Story* (Cambridge: Cambridge University Press, 1985) — in which Cairns-Smith proposes that organic life emerged from clay crystals — and notes that in humankind's near future there is going to be another 'genetic takeover' (p. 3), as our machines eventually become totally independent of their creators in terms of maintenance and reproduction.

In his discussion on machine evolution Moravec uses another argumentative strategy based on the logic of incremental series. This time, however, instead of creating a single series, he juxtaposes two series in order to create a double hierarchy argument. Observing how different methods of achieving intelligence in machines — such as the traditional AI technique of attempting to copy the mental processes of humans and the cybernetic approach of modelling neural systems of animals — have produced important discoveries in the field of artificial intelligence studies, Moravec states that 'the fastest process can be made by imitating the *evolution* of animal minds, by striving to add capabilities to machines a few at a time' (p. 17; emphasis original). In doing so, he uses the incremental series that portrays organic evolution as a model for describing and predicting the nature of machine evolution, thus employing argumentation based on the comparison of two parallel series. 'By setting up experimental conditions analogous to those encountered by animals in the course of evolution,' he continues, 'we hope to retrace the steps by which human intelligence evolved' (p. 17). This passage makes clear that the relationship between the two models of evolution is based on an analogy between two series of events, which is exactly how double hierarchy arguments are formed.

Aided by the juxtaposition of the double hierarchy argument, Moravec proceeds to envision how machines might evolve into conscious beings. For this purpose, he employs the concept of convergent evolution, 'used by evolutionary biologists whenever species that are only very distantly related independently develop similar characteristics, presumably in response to similar environmental pressures' (p. 39). In order to illustrate how a simple robot's actions might be understood in terms of the qualities we normally ascribe to living, conscious beings, Moravec describes a humorous thought experiment in which a robot is instructed to fetch a cup from a room. While executing the task, the robot encounters problematic conditions and situations, such as poor lighting (which makes it difficult for the robot to detect the right door) and travelling in stairs (which places the robot in 'mortal danger' (p. 41)). Next Moravec notes that a person observing the robot might be tempted to use anthropomorphic language to describe its reactions to such problems and continues:

> We could chastise the person, but in my opinion that would be wrong. The robot came by its foibles and reactions as honestly as any living animal; the observed behavior is the correct course of action for a being operating with uncertain data in a dangerous world. An octopus in pursuit of a meal can be diverted by subtle threats of danger in just the way the robot was. The invertebrate octopus also happens to have a nervous system that evolved entirely independently of our own vertebrate version. Yet most of us feel no qualms about ascribing qualities like passion, pleasure, fear, and pain to the actions of the animal. The needs of the mobile way of life have conspired in all three instances to create an entity that has modes of operation for different circumstances and that changes quickly from mode to mode on the basis of uncertain and noisy data prone to misinterpretation. As the complexity of mobile robots increases, their similarity to animals and humans will become even greater. (p. 42)

This passage shows that the form of the double hierarchy argument plays an instrumental role in Moravec's reconfiguration of the human-machine dichotomy. By drawing an analogy between the modes of behaviour of the representatives of the two categories, Moravec is able to build a rhetorically persuasive case for the blurring of the boundary between them. Indeed, he notes that 'the spider's nervous system is an excellent match for robot programs possible today [in 1988]' (p. 43), thus using a feature of an organic being as a point of comparison for the status quo of artificial intelligence in the late 1980s.

Yet another example of Moravec's use of the logic of double hierarchy arguments is evident in his discussion of the neural circuitry of the human brain. He focuses especially on the eye's retina, describing its function at length, and eventually draws a comparison between the eye and a TV monitor:

> The TV I have been referring to is not totally imaginary. Sitting next to me as I write is a TV monitor that often displays images just like those described. They come not from an animal's retina but from the eye of a robot. The picture from a TV camera on the robot is converted by electronics into an array of numbers in computer memory. Programs in the computer combine these numbers to deduce things about the robot's surroundings. Though designed with little reference to neurobiology, many of the program steps strongly resemble the operations of the retinal cells — a case of convergent evolution. (p. 57)

Employing the organic as a model for the artificial, the passage foregrounds the similarity between the two. As Moravec is keen to highlight such similarities, it is perhaps not surprising that he at the same time portrays living things in terms of artificial characteristics. For instance, he describes how we may imagine that at the level of molecules 'proteins have moving parts like hinges, springs, and latches triggered by templates. Others are primarily structural, like bricks or ropes or wires. The proteins of muscle tissue work like ratcheting pistons' (p. 72). The three similes suggest that to a considerable extent, organic beings are comparable to machines, indicating that in addition to incrementum, the logic underlying convergent evolution could be described by antimetabole: while machines are like organic beings, organic beings are like machines.

After outlining his evolutionary vision in this way, Moravec goes on to focus on the implications of the blurring of the boundary between men and machines at the next stage of their joint evolution. In particular, he argues against what he calls the body-identity position, a question that also concerns Roger Penrose in *The Emperor's New Mind*. Because this position maintains that human identity is inextricably linked to the constituents of the physical body, it would be impossible — as Moravec envisions happening in the future — to separate the mental from the physical by copying the former to computer memory without destroying the identity of the individual copied (pp. 116–17).

As an alternative to this view, he proposes a pattern-identity position that ‘defines the essence of a person […] as the *pattern* and the *process* going on in my head and body, not the machinery supporting that process. If the process is preserved, I am preserved’ (p. 117; emphases original). Using antithesis, Moravec strictly separates matter from its pattern. Note also how the last sentence uses alliteration and epistrophe in order to create a slogan-like epitome of the pattern-identity position’s most important implication for human identity: while alliteration strongly identifies process with preservation, the repetition of the word *preserved* links process to identity and creates even a wider gap between the impermanence of physical existence and the permanence of mental life.

Moravec’s transhumanist position thus aims to build a conceptual gap between matter and identity by linking the latter to patterns. In order to illustrate the implications of the pattern-identity position, Moravec makes use of an analogy between information and identity. ‘Consider the message, “I am not jelly.”’, he proposes

As I type it, it goes from my brain into the keyboard of my computer, through myriads of electronic circuits, and over great amounts of wire. After countless of adventures, the message shows up in bunches of books like the one you are holding. How many messages were there? I claim that it is most useful to think there is only one, despite its massive replication. If I repeat it here: “I am not jelly,” there is still only one message. Only if I change it in a significant manner (“I am not peanut butter”) do we have a second message. (p. 118)

The passage foregrounds the idea that even though the individual constituents (letters) of the first message are replaced by similar constituents in the second one, the pattern in which the message is arranged is not altered in any way. Moravec then uses another antithesis to epitomize the implications of his analogy: ‘The message is the information conveyed, not the medium on which it is encoded. The “pattern” that I claim is the real me has the same properties as this message' (p. 119). In this case we could say that the linguistic form of antithesis embodies the strong body-mind dualism of the pattern-identity position while buttressing Moravec's claim that in the future it will be possible to copy individuals atom for atom and molecule for molecule without changing their fundamental identities.

* * *

In contrast to the analyses in 5.2, the ones is this subchapter represent the relationship between humankind and its machines in terms of an eventual fusion. Because of the authors' similar arguments, the popular science of Ray Kurzweil and Hans Moravec in *The Age of Spiritual Machines* and *Mind Children*, respectively, displays similar rhetorical strategies. Firstly, both portray the notion that evolution is heading towards the birth of intelligent machines by envisioning an incremental series that does not end at the current form of humankind. Secondly, both picture the co-evolution of humans and machines in a way that points to the reciprocal logic suggested by the linguistic form of antimetabole. Kurzweil's use of various types of repetition in turn linguistically accommodates the idea that technological evolution is a self-sustaining process that continuously creates more and more sophisticated products. Characteristic of Kurzweil's argument is also the employment of consciousness as an umbrella term that proposes that there is only a quantitative difference between humans and other forms of intelligent life. Moreover, in his analogies that place humankind and technology side by side Kurzweil antithetically separates mind from body, arguing for the victory of the metaphorical software of mind over the equally metaphorical hardware of body.

Although Moravec's rhetoric is to a considerable extent based on the same kinds of analogies that Kurzweil employs, it tends to present them through the form of double hierarchy arguments. Like that of Kurzweil's umbrella terms, the main function of such juxtapositions of two series is to reconfigure the human-machine dichotomy. Finally, like Kurzweil, Moravec uses antithesis in order to separate matter from identity, thus strengthening the mind-body dichotomy of transhumanism.

5.3.2 Humankind Merging with Machines

The notion of machines becoming sentient has for a long time been a characteristic feature of portrayals of technological development in science fiction. Its origins, however, can be traced outside the genre proper to nineteenth-century precursors, such as Mary Shelley's *Frankenstein* (1818) and Samuel Butler's *Erewhon* (1872).[182] The actual images of robots and machine intelligence did not appear until the first three decades of the twentieth century: the Czech writer Karl Čapek's satire *R.U.R* (1921) introduced the word *robot* into general vocabulary, while fantasy and horror fiction pulp magazines, such as *Weird Tales*, published short stories in which machines become sentient. For instance, the British science fiction writer S. Fowler Wright's short story 'Automata' from the end of the 1920s

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[182] Patricia S. Warrick, *The Cybernetic Imagination in Science Fiction* (Cambridge, Mass.: MIT Press, 1980), pp. 35–43. Further references to this book are given in parenthesis.

explicitly portrays machine intelligence as the next stage of technological evolution (Warrick, pp. 48–51).[183]

I begin my examination of the portrayal of artificial intelligence in contemporary literature by discussing the work of a writer who raised the question of machine intelligence among the most important themes in science fiction: Isaac Asimov. Along with the genre's influential early authors such as John W. Campbell, Asimov put the thematic focus of science fiction on the interaction of machines (robots and computers) and humankind in his robot stories, which were published in collections such as *I, Robot* (1950), *The Rest of the Robots* (1964), and *The Bicentennial Man* (1976). As Patricia S. Warrick has noted, these stories tend to explore the following themes:

> the political potential of the computer, the uses of computers and robots in space exploration and development, problem solving with computers, the differences between man and machine, the evolution of artificial intelligence, [and] the ethical use of technology. (p. 57)

Using some of Asimov's most famous stories as examples, I concentrate especially on the third, fourth, and fifth themes, as they are the most pertinent ones for my overall discussion.

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[183] From such beginnings the relationship between humankind and its technology has become a major focus for writers. In his analysis of the so-called cybernetic fiction, David Porush discusses the relationship between cybernetics, the science of communications and automatic control systems in machines and organic life, and the fiction of writers such as Kurt Vonnegut, William S. Burroughs, Thomas Pynchon, John Barth, Samuel Beckett, Joseph McElroy, and Donald Barthelme. He argues that cybernetic fiction has emerged as a response to the anxieties produced by the mechanistic view of human communication and intelligence in cybernetics. David Porush, *The Soft Machine: Cybernetic Fiction* (New York: Methuen, 1985), p. 16. Further references to this book are given in parenthesis. According to Porush, cybernetic fiction not only offers representations of machines but also draws attention to the idea that language, writing, and texts are metaphorical machines as well, as much of self-reflexive postmodernist fiction is concerned with laying bare the linguistic machinery that produces texts (pp. 18–23). As such, the machine metaphor points to a fundamental paradox of human existence: it signifies 'the sheer predictability […] of the mechanism of the models we employ to describe our world and selves that we have grown from empirical evidence' while simultaneously being 'an expression of our inventiveness and freedom' (p. 13). Thus, contemporary fiction both uses and resists the metaphor — often in order to suggest a creative resolution to the paradox (p. 23).

In 'The Evitable Conflict' (1950), an early robot story, humankind is under the threat of a 'final war'[184] in the twenty-first century. The production rates in the world's four major regions have dropped, and the investigators working on the problem face the task of finding out its cause. Because the productivity of each region is controlled by a computer, collectively referred to as 'the Machines', the central question the investigators have to answer is whether it is the computers or the humans feeding them data that should be held responsible for the undesirable development. They soon find out that the Machines have been deliberately fed erroneous information by humans opposing the use of computers — one of the saboteurs is an engineer who belongs to 'The Society of Humanity' (p. 265), a clandestine movement seeking to replace computers with human workers. Thus, because of their harmful efforts, the society's members — whose behaviour, it is later revealed, ultimately stems from their prejudiced pride — have brought humankind close to war. Significantly, it is suggested that human disregard for the good of the whole will cause a major regression in moral evolution: 'If popular faith in the Machines can be destroyed to the point where they are abandoned, it will be the law of the jungle again' (p. 272), as one of the characters notes. The Machines, in contrast, are portrayed working 'not for any single human being, but for all humanity' (p. 274). In short, then, the Machines represent a higher form of not only technological but also moral development.

However, for our discussion on the relationship between humankind and its machines, the most significant feature of 'The Evitable Conflict' is how it foregrounds the question

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[184] Isaac Asimov, 'The Evitable Conflict', in *Machines that Think: The Best Science Fiction Stories about Robots and Computers*, ed. by Isaac Asimov, Patricia S. Warrick, and Martin H. Greenberg (New York: Holt, Rinehart and Winston, 1983), pp. 251–76 (p. 253). Further references to this short story are given in parenthesis.

about the differences between human and machine judgement. One of the investigators, Dr Susan Calvin of the U. S. Robots and Mechanical Men Corporation, who appears also in many other robot stories, describes the problem solving capabilities of the Machines to another character as follows:

> Every action by any executive which does not follow the exact directions of the Machine he is working with becomes part of the data for the next problem. The Machine, therefore, knows that the executive has a certain tendency to disobey. He can incorporate that tendency into that data — even quantitatively, that is, judging exactly how much and in what direction disobedience would occur. Its next answers would be sufficiently biased so that after the executive concerned disobeyed, he would have automatically corrected those answers to optimal directions. The Machine *knows*, Stephen! (pp. 273–74; emphasis original)

Because the Machines are fundamentally self-correcting entities, Dr Calvin suggests, they are incapable of producing inaccurate information. Consequently, although they were fed erroneous information by The Society of Humanity, there is nothing wrong with calculations of the Machines as such, since the productive imbalance is just a temporary matter caused by the process of self-correction. In terms of calculation, then, the Machines are clearly superior to humans. ‘We’, Dr Calvin notes, ‘haven’t at *our* disposal the infinite factors that the Machine has at *its*!’ (p. 275; emphases original). Hence, the kind of judgement that the Machine shows in the passage is necessarily based on the mechanical calculation of certain statistical tendencies in human behaviour, not on conscious thought or intuitive evaluation.

This important difference is even more clearly articulated in another passage. Dr Calvin explains the computer coordinator Stephen Byerley that although their calculations are precise, it would be wrong to say that the Machines are capable of knowing each and every aspect of a particular situation. She illustrates this through an example describing the evaluation of cotton's quality:

> "[…]. The cotton industry engages experienced buyers who purchase cotton. Their procedure is to pull a tuft of cotton out of a random bale of a lot. They will look at that tuft and feel it, tease it out, listen to the crackling perhaps as they do, touch it with their tongue — and through this procedure they will determine the class of cotton the bales represent. […]. Now these buyers cannot yet be replaced by the Machine."
> "Why not? Surely the data involved is not too complicated for it?"
> "Probably not. But what is this data that you refer to? No textile chemist knows exactly what it is that the buyer tests when he feels a tuft of cotton. Presumably there's the average length of the threads, their feel, the extent and nature of their slickness, the way they hang together, and so on — several dozen items, subconsciously weighed, out of years of experience. But the *quantitative* nature of some of them is not known. So we have nothing to feed the Machine. Nor can the buyers explain their own judgment." (p. 270; emphasis original)

The passage suggests that for Asimov, there is an important difference between the ways in which humans and machines exercise judgement: while human judgement always contains an intuitive element (the subconscious evaluation of the quality of cotton), machine judgement is based purely on calculation. Therefore, Asimov's portrayal of the differences between human and machine judgment in 'The Inevitable Conflict' is based on the same basic argument that Joseph Weizenbaum and Roger Penrose make in their books: there is a qualitative difference between the two.

True to his scientific optimism, however, Asimov at the same time proposes that the calculative logic of the computer can be utilized to secure a better future for humankind. At the beginning of the story Calvin and Byerley note that human history has always contained an element of inevitability in that conflicts such as wars show that history is 'endlessly cyclic' (p. 253). Yet the superior calculating skills of the Machines that give them 'the absolute control of […] economy' (p. 276) make it possible to change the nature of history, so that instead of inevitable wars there is progress towards increasingly developed forms of society. Thus, Asimov suggests, machine control is a better alternative for the various kinds of phenomena that have shaped humankind's existence in the past. Indeed, for Dr Calvin humankind 'was always at the mercy of economic and sociological forces it did not understand — at the whims of climate, and the fortunes of war' (p. 276). The Machines, in contrast, 'understand' (p. 276) these phenomena through their skills in calculation, and are consequently able to control them, securing the survival of humankind.

Asimov's robot novels are similar meditations on the relationship between humankind and its machines. This focus is evident, for instance, in *The Caves of Steel* (1954), which, along with *The Naked Sun* (1956), examines the relationship by blending science fiction with the detective story. The human protagonist of *The Caves of Steel*, the detective Elijah Baley, is given the task of solving a case involving the murder of a 'Spacer', a member of a population living in the extraterrestrial 'Outer Worlds', to which the inhabitants of the Earth have an uneasy relationship. In order to catch the perpetrator, Elijah is assigned a partner named R. Daneel Oliwav, an anthropomorphic robot designed by the Spacers. As the investigation proceeds, it is revealed that Daneel has been sent to the Earth not only to do detective work but also to persuade humans of the plausibility of the idea of forming an alliance between the Earth and the Outer Worlds. However, because of humankind's distrust of both the Spacers and robots — the latter are used as servants and employees in menial tasks — the alliance meets strong resistance. A clandestine group called Medievalists (note the similarity to The Society of Humanity) opposes modernization by embracing humankind's past, which they regard free of the complications of the present and the future. Not surprisingly, the end of the novel reveals that a Mediaevalist, who is actually the police commissioner for whom Elijah works, is responsible for the murder. In order to halt the process of modernization, the commissioner had accidentally killed Daneel's creator, although his plan had been to dispose of the robot. As in 'The Evitable Conflict', then, Asimov approaches the question about the relationship between humankind and technological progress through a portrayal of a process of finding a solution to a social problem.

By pairing Elijah and Daneel for a common task, Asimov is able to highlight the similarities and differences between humans and machines. At first the attitude of the former towards the latter is characterized by mistrust and even hostility. On their way to meet Elijah's family, the two detectives come across a riot scene in front of a shoe store: a female customer has become enraged by what she sees as lack of attention from the store's robot attendants, and the commotion causes an angry crowd to demand the destruction of the robots. Daneel succeeds in dispersing the crowd, but Elijah feels that he has endangered their mission by acting in too conspicuous a manner in public, reprimanding his partner for this by reminding him that he is 'nothing more than a robot'.[185] Daneel's response, however, suggests that his partner's critique is misdirected. 'The division between human and robot', he says, 'is perhaps not as significant as that between intelligence and nonintelligence' (p. 37), thus anticipating Ray Kurzweil's and Hans Moravec's notions of intelligence as not exclusively being a human trait. Indeed, rather than remaining completely separate from each other, the organic and the artificial occasionally seem to merge in the story. The most obvious example of this is the fact that Daneel's appearance

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[185] Isaac Asimov, *The Caves of Steel* (London: Boardman, 1954; London: HarperCollins, 1997), p. 36. Further references to this book are given in parenthesis.

and manners are so human-like as to be indistinguishable from those of humans. Conversely, in the overpopulated and exceedingly efficient world of the caves of steel — the title of the novel refers to the architecture of the Earth's cities, which resemble 'tremendous, self-contained cave[s] of steel and concrete' (p. 23) — human behaviour appears to some extent become mechanized. Just as the narrator makes repeated references to the 'unemotional' (p. 25) composition of Daneel, so Elijah's behaviour is described in terms that suggest certain mechanicalness of character. For instance, when first meeting Daneel, he approaches the robot 'woodenly' and presents himself 'in a monotone' (p. 25). Similarly, meeting his future wife for the first time, Elijah smiles to her 'mechanically' (p. 38). Of the police commissioner and Medievalist Julius Enderby, the narrator notes that he 'fit the administrative machine perfectly' (p. 63). Descriptions such as these could be argued to reflect the mechanizing effect of a society that has sacrificed 'space, privacy, [and] even much of free will' (p. 61) for increased productivity. Indeed, describing the procedure of taking a shower in one of the city's common shower rooms, the narrator notes that 'Baley felt like a machine tool being shaped by long-distance force edges on an assembly line' (p. 73).

However, in spite of metaphorical similarities such as these, Asimov maintains that human beings and machines are qualitatively different and, as in 'The Evitable Conflict', states the difference in explicit terms. 'A human brain,' the roboticist Anthony Gerrigel explains to Baley, who is doubtful of Daneel's sincerity, 'or any mammalian brain, cannot be completely analyzed by any mathematical discipline now known' (p. 139). Daneel's positronic brain, in comparison, must be 'completely analyzable, or it could not be constructed' (pp. 139–40). Moreover, like Weizenbaum, Asimov suggests that the ability to form judgments should be considered as an ability unique only to the human species. This is evident in Elijah's explanation of the biblical story about the stoning of an adulterous woman, which he uses to illustrate the difference between codes of conduct such as those given in the Bible and secular law. Because he has been programmed to follow the latter to the letter, the end of the story leaves Daneel puzzled:

> "And the woman was guilty?"
> "She was."
> "Then why was she not stoned?"
> "None of the accusers felt he could after Jesus's statement. The story is meant to show that there is something even higher than the justice which you have been filled with. There is a human impulse known as mercy; a human act known as forgiveness."
> "I'm not acquainted with those words, partner Elijah." (p. 161)

Indeed, Daneel's skill as a detective is based on his superior ability to calculate and analyse. He is able to make instant brains scans that he uses to explain and predict behaviour, consequently — correctly, it is revealed — noting that 'the cerebro-analytic properties of the Commissioner are such that it is impossible for him to have committed deliberate murder' (p. 200). Yet the novel makes it clear that Daneel's mechanical analysis of human behaviour needs to be complemented by Elijah's human judgment. Foregrounding the decisive role of that part of the human mind that eludes analysis, the narrator gives a detailed account of the process that leads to the solution of the case:

> It was in that way that the "sentence" he had been waiting for came to Elijah Baley, and the opaque jelly shuddered and settled and changed into luminous transparency.
> […].
> It could not all have burst full-grown into his mind. Things did not work so. Somewhere, deep inside his unconscious, he had built a case, built it carefully and in detail, but had been brought up short by a single inconsistency. One inconsistency that could be neither jumped over, burrowed under, nor shunted aside. While that inconsistency existed, the case remained buried below his thoughts, beyond the reach of his conscious probing. (p. 189)

After Enderby has confessed the mistaken killing of Dr Sarton, the Spacer at first thought to have been murdered, Daneel has to admit the insufficient explanatory power of his calculations (‘I was thrown completely off the scent by the Commissioner’s cerebroanalysis’ (p. 204)), with the narrator implying that Elijah’s idea about Enderby’s guilt was intuitive (‘I had no evidence that would stand up in court, only inferences’ (p. 204)).

While these passages outline the major differences between humans and machines in clear-cut terms, there are other examples that in the same way focus on the line between calculation and judgment as the essential divide between them. Human emotions, for instance, are from Daneel’s viewpoint merely calculable patterns that cerebroanalysis reveals. As such, they are devoid of any extraneous meaning and considered inferior to mathematical analysis, as his definition of curiosity shows: ‘Aimless extension of knowledge […] which is what I think you really mean by the term curiosity, is merely inefficiency’ (p. 189). Another difference, to which Asimov repeatedly points in his fiction, is machines’ inability to understand figurative language: confronted by sarcasm on Baley’s part, Daneel shows ‘no sign of any awareness’ (p. 189) of the fact that he is being ridiculed.

By highlighting the various similarities and differences between robots and humans, Asimov seeks to show that the two are neither completely similar nor completely different, thus suggesting the need for reconciliatory thinking. Significantly, we learn that Dr Sarton’s work on robotics was based on a vision of a ‘C/Fe’ (p. 55) culture, a creative juxtaposition of carbon- and iron-based forms of life. Instead of a complete merger, however, the idea of the new culture rests on a clear-cut division concerning the identities and tasks of the representatives of human and machine intelligence — an idea symbolized by the image of

Elijah and Daneel leaving the Commissioner's office 'arm in arm' (p. 206) at the end of the novel.

In 'The Bicentennial Man' (1976), which was published in an eponymous collection, Asimov approaches the question about the relationship between humankind and machines from the viewpoint of ethics. If machine intelligence continues to develop to the point of human-like complexity, he asks, is it possible that in the future humankind has to grant its machines the same rights it now grants to its own members? From the viewpoint of the questions explored in this chapter, the story is relevant because in order to answer the ethical question, it needs to address the related question concerning the difference between human and machine intelligence. Moreover, Asimov also studies the relationship between the organic and the artificial, pondering on the question whether it is possible to draw a clear-cut line between the two.

The protagonist of the story, Andrew Martin, is a robot who desperately desires to become a human being. During the time-span of two hundred years, Andrew gradually turns from a servant of the Martin family to a more or less independent — free — individual who to a considerable extent is indistinguishable from humans. In addition to modifying his external appearance and developing skills such as carpentry, Andrew fights a lengthy legal battle in order to be recognized as a full member of the human species. To his disappointment the World Court eventually decides against him because his brain differs from the human brain. 'Your brain', Andrew's advisor explains the decision to him,

> is manmade, the human brain is not. Your brain is constructed, theirs developed. To any human being who is intent on keeping up the barrier between himself and a robot, those differences are a steel wall a mile high and a mile thick.[186]

For Andrew, however, the real issue behind the decision is immortality: because he has an artificial brain, he would become the first human being to achieve it were he granted the legal status of a human. As in the face of human opposition to the idea it is clear that this cannot happen, Andrew decides to sacrifice his immortality by undergoing an operation in which his artificial brain is connected to 'organic nerves' (p. 559) in order to become a true member of humankind.

For the purposes of the present discussion, the most significant feature of 'The Bicentennial Man' is found in the way in which it portrays the link between intelligence and identity. As part of the process of becoming more human, Andrew approaches the U. S. Robots and Mechanical Men Corporation, and requests to be 'replaced by an organic robot, an android' (p. 543). However, this, as the representative who meets Andrew suggests, poses a major problem: 'How can I replace you for you? If I replace you, as robot, how can I donate the new robot to you as owner since in the very act of replacement you cease to exist' (p. 543). Paul Martin, who accompanies Andrew to the meeting, insists that there is no fundamental obstacle to fulfilling the request:

> The seat of Andrew's personality is his positronic brain, and it is the one part that cannot be replaced without creating a new robot. The positronic brain, therefore, is Andrew the owner. Every other part of the robotic body can be replaced without affecting the robot's personality, and those other parts are the brain's possessions. Andrew, I should say, wants to supply his brain with a new robotic body. (p. 543)

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[186] Isaac Asimov, 'The Bicentennial Man', in *Machines that Think: The Best Science Fiction Stories about Robots and Computers* (see Asimov, Warrick, and Greenberg, above), pp. 519–61 (p. 558). Further references to this short story are given in parenthesis.

Note how closely the notion of the brain as the origin of personality — or identity — reflects the gist of the arguments of Kurzweil and Moravec: the individual consciousness does not require a body in order to exist. Significantly, this is the idea that Andrew mentions when he realizes that immortality marks the final boundary between the human and the non-human. 'What matters', he concludes, 'is that brain cells die; *must* die. Even if every other organ in the body is maintained or replaced, the brain cells, which cannot be replaced without changing and therefore killing the personality, must eventually die' (p. 559; emphasis original). Just as the transhumanists Kurzweil and Moravec, then, Asimov suggests that the survival of the species might necessitate the separation of mind from body and the storing of the former in a form immune to disintegration.

Even if Asimov's story does not go as far as Kurzweil and Moravec in imagining the future of humankind as existence in some disembodied realm of virtual reality, it nevertheless offers a definite vision of the co-evolution of humans and technology in which machines acquire human characteristics and humans become increasingly machine-like in a self-perpetuating loop, as suggested by the reciprocal logic of antimetabole. Andrew becomes increasingly human in terms of not only his external appearance but also his inner life. 'When you talk to him,' one of the Martins remarks, 'you'll find that he reacts to the various abstractions as you and I do, and what else counts? If someone else's reactions are like your own, what more can you ask for?' (p. 528). Just as Kurzweil and Moravec with their analogies that aim to reconfigure the human-machine dichotomy, so this character insists that machines should be granted the status of conscious beings if they manage to convince us of being conscious beings. It is also Andrew's longing for freedom that makes him human-like in his aspirations. Although his behaviour is regulated by the Three Laws of Robotics,[187] it is at the same time suggested that human beings are also 'bound by their laws' (p. 530) — in this respect, then, machines and humans are similar. Moreover, Andrew becomes more and more human-like in his moral behaviour: being subjected to the laws, he cannot lie but nevertheless persuades Paul Martin to lie to the head of U. S. Robots in order to secure a meeting (p. 541). In the meeting Andrew accepts Paul's strategy of threatening the head with a lawsuit if he does not comply with his wish of installing his brain into an android body, which also constitutes an obvious gesture of defying human authority.

In contrast, as Andrew becomes increasingly human-like, some of the human characters in the story acquire the characteristics of their machines. For instance, in order to combat the effects of aging on his eyesight, Paul has his eyes 'replaced with photoptic cells' (p. 547), thus combining the organic with the inorganic in his own body. In the same way, at the testimonial dinner of Andrew's one hundred and fiftieth anniversary, the ninety-four-year-old Director of Research at U. S. Robots sports 'prosthetized devices' (p. 552) that have replaced his liver and kidneys, thus allowing him to live longer. This again testifies of the fact that the underlying logic of co-evolution is the reciprocal logic of antimetabole.

What these examples suggest, then, is that in Asimov's fiction, it may not be possible to separate humans from machines in any simple way. The fact that the organic can be

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[187] Asimov outlines these in his short story 'Runaround' (1942) as follows: '1. A robot may not injure a human being, nor through inaction allow a human being to come to harm. 2. A robot must obey the orders given to it by human beings except where such orders would conflict the First Law. 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law'. Isaac Asimov, 'Runaround', in *Machines that Think: The Best Science Fiction Stories about Robots and Computers* (see Asimov, Warrick, and Greenberg, above), pp. 209–29 (p. 209).

replaced by the inorganic and vice versa indicates that there is no absolute boundary between humankind and its technological creations. As such, the two exist on a continuum rather than as the opposing sides of a dichotomy (Warrick, p. 73). Hence, as in the model of evolution presented in the popularizations of Kurzweil and Moravec, there is a continuum of intelligence that manifests itself through a variety of beings, both organic and inorganic.

*   *   *

The portrayal of the relationship between men and machines as intimate co-evolution is even more pronounced in the work of Arthur C. Clarke. In his space odyssey tetralogy, which consists of the books *2001: A Space Odyssey* (1968), *2010: Odyssey Two* (1982), *2061: Odyssey Three* (1988), and *3001: The Final Odyssey* (1997), readers are offered an evolutionary vision in which humankind and its technological creations evolve progressively through increasingly complex and sophisticated forms towards a future very similar to that depicted in the post-humanist theories of Ray Kurzweil and Hans Moravec. Like Asimov but with a more pronounced fusion of the organic and the inorganic, Clarke depicts the boundary between humans and machines in terms of a process that moulds them both. While machines in Clarke's fiction become sentient creatures, some of his protagonists fuse with them, thus assuming the status of disembodied intelligences that appear to be spiritually more evolved than the flesh-and-blood members of humankind.

2001, which was written on the basis of the screenplay for Stanley Kubrick's eponymous film, explores the possibility that human evolution is guided by an alien race of intelligent beings. Beginning in the early days of humankind's evolution, the story introduces the image of a black monolith, which eventually becomes an important motif in all parts of the tetralogy. It soon becomes evident that the function of the monolith is to propel the ancestors of humankind to the next stage of evolution by teaching them to use sticks, stones, and bones as primitive means of controlling their surroundings. The contact with the monolith hence launches a co-evolutionary process in which technology and its human creators are shaped by each other:

> The tool-makers had been remade by their own tools.
> For in using clubs and flints their hands had developed a dexterity found nowhere else in the animal kingdom, permitting them to make still better tools, which in turn had developed their limbs and brains yet further. It was an accelerating, cumulative process; and at its end was Man.[188]

With the syntactic formulation of the first sentence of the second paragraph suggesting a loose antimetabole, the passage portrays the relationship between humankind and technology as a self-perpetuating process in which the organic shapes the inorganic and vice versa. Like Kurzweil and Moravec with their emphasis on the reciprocal nature of co-evolution, then, Clarke shows how humans and technology have been inseparable from each other right from the beginning of evolution and how this bond is what ultimately determines the direction of their development.

As its evolution reaches the twenty-first century, humankind comes into contact with another monolith. Introduced through Dr Heywood Floyd's trip to Clavius Base, a space research base on the Moon, the T.M.A.-1 functions as a signalling device that has been placed on the satellite of the Earth in order to inform the alien intelligence about

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[188] Arthur C. Clarke, *2001: A Space Odyssey* (London: Hutchinson, 1968), p. 38. Further references to this book are given in parenthesis.

humankind's exploration of the solar system. Like the decisive step of learning to use tools, space travel is a disjunctive point in the co-evolution of humans and machines, as the spaceship sent to investigate the origin of the monolith is equipped with the HAL 9000 computer, metaphorically described as 'the brain and nervous system of the ship' (p. 107). Explaining the history of artificial intelligence, the narrator observes that

> In the 1980's, Minsky and Good had shown how neural networks could be generated automatically — self-replicated — in accordance with any arbitrary learning programme. Artificial brains could be grown by a process strikingly analogous to the development of a human brain. In any given case, the precise details [of this process] would never be known, and even if they were, they would be millions of times too complex for human understanding. (p. 107)

Anticipating Kurzweil and Moravec, Clarke makes two fundamental assumptions about the future of human technology. Firstly, he raises the post-humanist argument by stating that the evolution of organic intelligence can be used as a model in the education of inorganic intelligence, thus implicitly suggesting that it would be possible to conceptualize the relationship between humans and machines not as a rigid opposition but as a continuum of intelligence. Secondly, the passage proposes that machines might one day become independent of human control, as humankind grows incapable of understanding their complexity, which is another basic assumption that the proponents of the strong version of AI theory often make.

These views are evident in the portrayal of *Discovery's* journey to the vicinity of Jupiter to investigate the source of the messages received by the monolith. Most of the communication between Hal and the crew members Frank Poole and David Bowman takes place through conversation — as the latter remarks Hal meets the requirements of the Turing test by delivering the unquestionable impression of engaging in the process of thinking (p. 108). More suggestively, however, Hal is shown to be capable of sentiments usually associated only with humans. As it encounters the conflict whether to conceal the truth about the mission's real purpose or to reveal it to the human passengers, Hal becomes increasingly agitated. 'He had begun to make mistakes,' the narrator observes, 'although, like a neurotic who could not observe his own symptoms, he would have denied it' (p. 171). The simile indicates that in a suggestive contrast to Poole and Bowman who quite mechanically repeat their tasks in the ship, it is the machine that actually experiences some of the deepest emotions during the journey. When Bowman begins to notice the strangeness of Hal's actions, the narrator makes a revealing comparison between the panic experienced by Bowman and Hal's behaviour:

> And panic was something that Bowman understood, better than he had any wish to, for he had known it twice during his life. The first time was as a boy, when he had been caught in a line of surf and nearly drowned; the second was as a spaceman under training, when a faulty gauge had convinced him that his oxygen would be exhausted before he could reach safety.
>
> On both occasions, he had almost lost control of all his higher logical processes; he had been within seconds of becoming a frenzied bundle of random impulses. Both times he had won through, but he knew well enough that any man, in the right circumstances, could be dehumanised by panic.
>
> If it could happen to a man, then it could happen to Hal; and with that knowledge the bitterness and the sense of betrayal he felt towards the computer began to fade. (pp. 195–96)

In addition to suggesting that Hal is capable of truly experiencing human emotions instead of merely simulating them, the passage contains a revealing reversal of human and machine behaviours. While panic makes Bowman's behaviour machine-like, the experience of the same emotion in Hal gives the computer a definite human characteristic, which implicitly suggests a reconfiguration of the human-machine dichotomy. Moreover, the last paragraph makes it clear that Bowman's attitude towards Hal is characterized by empathy, implying that he considers the computer as an entity with status equal to that of a human being.

Another example of mechanical human behaviour as an indicator of such reconfiguration is Bowman's reaction to Poole's death. Except for a fleeting moment, the loss of his shipmate does not seem to emotionally affect Bowman:

> For an instant, Bowman felt the skin prickling at the base of his scalp. The words he was about to call died suddenly on his parched lips. For he knew that his friend could not possibly be alive; and yet he had waved […].
>
> The spasm of hope and fear passed instantly, as cold logic replaced emotion. The still accelerating pod was merely shaking the burden it dragged behind it. Poole's gesture was an echo of Captain Ahab's when, lashed to the flanks of the white whale, his corpse had beckoned the crew of the *Pequod* on to their doom. (p. 162)

After Poole has disappeared from his sight, Bowman's feelings concerning the event are concentrated on the thought that 'Frank Poole would be the first of all men to reach Saturn' (p. 163). Rather than expressing grief for the loss of his friend, the thought conveys a sense of jealousy and, perhaps, black humour. Moreover, after Bowman has become the only living crew member of *Discovery*, he tries to alleviate the oppressive sense of solitude by listening to music. Revealingly, he quickly comes to reject the 'emotional outpourings' of Romantic composers in favour of 'the abstract architecture of Bach' (p. 203) in order to remain functional.

Before vanishing into space, Poole too appears to be incapable of experiencing deeply meaningful emotions in the high technology environment of *Discovery.* An example of this is the beginning of the 'Birthday Party' chapter, which portrays Poole's birthday celebration. Poole watches and listens to his family singing their congratulations to him on a 'vision screen' (p. 135), but the event does not seem to give rise to any emotions in him.

Instead, he merely ponders on the technical aspects of the transmission, noting the time-lag that accompanies it. The distance separating him from his family is clearly both physical and mental: the narrator notes how Poole 'had moved into a new dimension of remoteness, and almost all emotional links had been stretched beyond the yield-point' (pp. 135–36). The immense distance from the Earth thus symbolically points to the effects of co-evolution, such as the diminishing of emotional life.

Finally, such blurring of boundaries between humans and machines is also evident in the way in which the novel portrays *Discovery* and its crew as parts of a seamless, unified whole. In the chapter entitled 'Cruise Mode' the rather uneventful life on the ship in the middle of the journey is depicted through a detailed description of the various duties Poole and Bowman must attend to. Interestingly, their lives are to a great extent regulated by the ship, to the point of developing an inner rhythm conditioned by the ship's devices. For instance, the narrator notes that Bowman had once deliberately switched off the alarm designed to awaken Poole for his duties, but the latter 'had still risen automatically at the right time' (p. 110), since any deviation from the strict schedule would be interpreted by Hal as a sign warning of a possible emergency. Moreover, the survival of the other crewmembers is entirely dependent on the ship's technology, as they hibernate until the journey back to the Earth. 'If there was any wisp of consciousness remaining,' the narrator notes of the sleeping colleagues of Poole and Bowman, 'it was beyond the reach of instruments, and of memory' (p. 102). In other words, they appear as lifeless as the inorganic parts of the vast machinery of *Discovery*.

This exploration of co-evolution continues in *2010*, as the abandoned *Discovery* is located by a Russo-American team of investigators. The task of recovering Hal is given to

Dr Chandra, a computer expert responsible for teaching the computer to understand and produce human language. Through the character of Chandra the novel presents the viewpoint of strong AI theory on the issue of drawing the boundary between humans and machines: for other crewmembers, Hal is ‘only a machine’, but Chandra insists that the difference between them and the computer is ‘merely a matter of degree’.[189] Readers, however, are not given an explicit answer to the question whether Hal is really capable of experiencing human emotions or whether he just successfully mimics them. Just as in *2001*, we are shown only the points of view of the humans observing the computer, which means that the idea of an artificial intelligence undistinguishable from human intelligence is offered as a speculative possibility.

Dr Chandra’s comment about intelligence distributed along a continuum rather than a property of only organic beings points to the end of *2001*, which portrays the next step of human evolution in terms of a radical separation between mind and body. Although the film version of the first part of the tetralogy ends with Bowman turning into a baby in an otherworldly copy of an earthly hotel (he discovers that the monolith on Japetus is actually a gate to a parallel universe), the novel follows his eventual metamorphosis into a disembodied being. By making Bowman the symbol of humankind’s new evolutionary direction, the novel suggests that the future of the species will be characterized by a disembodied form of existence. Clarke’s narrator is quite explicit about the ensuing mind-body dichotomy, and sees it as a chance to reconcile the opposition between the organic and the inorganic:

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[189] Arthur C. Clarke, *2010: Odyssey Two* (London: Granada, 1982), p. 172.

> And eventually; even the brain might go. As the seat of consciousness, it was not essential; the development of electronic intelligence had proved that. The conflict between mind and machine might be resolved at last in the eternal truce of complete symbiosis […].
>
> But was even this the end? A few mystically-inclined biologists went still further. They speculated, taking their cues from the beliefs of many religions, that mind would eventually free itself from matter. The robot body, like the flesh-and-blood one, would be no more than a stepping-stone to something which, long ago, men had called 'spirit'. (p. 201)

The passage implies that the tetralogy's view of evolution is based on the same kind of incremental logic as is the thinking of post-humanists such as Kurzweil and Moravec: because of its increasingly intimate co-evolution with machines, humankind is bound to evolve towards increasingly perfected forms, in the end attaining freedom from physical existence through a radical separation of mind from matter. The link to the ideology of post-humanism is further reinforced by the fact that the narrator's musings contain an obvious qualitative judgment, as it is revealed that for the alien race — which, as we shall see below, quite evidently symbolically represents the future of human evolution — there is 'nothing more precious than Mind' (p. 214) in the universe.

In *2010* Bowman learns that the alien race consists of 'a hierarchy of intelligences' (p. 144) that uses humans as tools for reaching an unknown evolutionary goal. It is also revealed that these intelligences, who are now nothing else than 'pure energy', had once been organic beings who had merged with machines in order to enhance their skills of space exploration, thus learning 'to preserve their thoughts for eternity in frozen lattices of light' (p. 199). In this way, Clarke uses his portrayal of the evolution of the alien race to draw an analogy to the evolution of humankind. In both cases there is the inevitable process of the merging of the organic and the inorganic: while the alien race, through the fusion with its machines, actually becomes its own technology ('They no longer built spaceships. They *were* spaceships' (p. 199; emphasis original)), humankind begins the same process, as is evident from the above discussion on the metaphorical mechanization of humans and the humanization of machines in *2001*.

The process leading to the fusion of humankind and machines reaches its conclusion at the end of *2061*, where readers are given more information about the role of the monoliths. Dr Heywood Floyd travels to Europa to examine an enormous monolith detected on the surface of the planet, and finds out that both Bowman and Hal have been integrated into it. This strange state of affairs is given an explanation in *3001*: it is revealed that the monolith is actually 'a fantastically powerful machine'[190] that possesses a vast intelligence but no consciousness, that is, it is an intelligent supercomputer. Symbolically, its union with Bowman represents another step forward in the process of the co-evolution of humankind and machines: while the monolith uses the disembodied astronaut to acquire the consciousness it lacks, Bowman has 'also been using *it*' (p. 191; emphasis original) in order to gain information about its superior technology. Once again the portrayal of the co-evolutionary relationship between the organic and the inorganic is based on the reciprocal logic of antimetabole, with the two continuously affecting the development of one another. Significantly enough, this process then culminates in the merger of Bowman and Hal, who are united into what to Frank Poole — Bowman's shipmate, as readers find out in the final part of the tetralogy, had not died after all — appears to be a single entity: 'Halman' (p. 199). This name functions to combine two apparently opposite entities, a human being and a machine, in the fashion of oxymoron, suggesting that the boundary between humankind and technology is now completely erased. Similarly, in the case of Poole there is evidence

[190] Arthur C. Clarke, *3001: The Final Odyssey* (London: HarperCollins, 1997), p. 191. Further references to this book are given in parenthesis.

of a considerable fusion of organic and inorganic elements: as he recovers from his cryogenic state after a thousand years, his brain is fitted with a Braincap, an information storage device that allows him to partake in virtual reality and to learn vast amounts of new information. Moreover, Poole discovers that third-millennium humans have nanoimplants containing personal information; such technology, as his mentor explains him, is ‘a part of you’ (p. 22). The characters of Halman and Poole hence embody the notion of co-evolution leading to an intimate merger of human consciousness and intelligent technology.

* * *

Many of the themes concerning the relationship between humans and machines in the science fiction of Isaac Asimov and Arthur C. Clarke also appear in the work of Philip K. Dick, but from another angle. Comparing Dick and Asimov, Patricia S. Warrick notes that although both of them suggest that the fusion of humankind and its machines is inevitable in the future, their views are considerably different: whereas Asimov, as we saw above, displays a marked optimism towards the co-evolution of the organic and inorganic, a deep sense of pessimism characterizes such mergers in Dick’s stories (pp. 206–07). What is more, in terms of narrative strategies Asimov and Dick tend to use different methods: while the former employs ‘discursive logic’ in order to structure stories — as already noted, Asimov’s characters solve puzzles through argumentation — the latter takes the opposite route by ‘[leaping] intuitively to a terminal metaphor’ (Warrick, p. 207). However, both hold the idea that humankind must regard itself as inextricably linked to other intelligent forms of life — including machines — as the key to the survival of the species.

If Asimov's 'The Bicentennial Man' implicitly argues that men and machines should be viewed as existing on a continuum of intelligent life, Dick's 'The Electric Ant' (1969) aims to show what is beneath the surface of human identity. To a certain extent resembling Kafka's famous treatment of the subject, the short story begins with the metamorphosis of the protagonist. Unlike Gregor Samsa, however, Garson Poole, a successful owner of an electronics company, does not metamorphose into a representative of the animal kingdom: while being treated in hospital for an accident, the doctor attending to him discovers that instead of being human, Poole is actually an electric ant. Indeed, as the story progresses Poole finds out that his life is not what it seems. Instead of owning the Tri-Plan Electronics company, he has been planted there by its actual owners, who 'wanted Tri-Plan run by an electric ant whom they could control'.[191] Returning home from the hospital, Poole tries to free himself from the outside control by manipulating a videotape that the owners have placed inside him in order to feed him their version of reality. Poole ends up deliberately cutting the tape, and dies after experiencing a vision in which hallucinatory images pass before his mind's eye.

Since Poole turns out to be an artificial construction rather than an organic being, the implicit suggestion in 'The Electric Ant' is that humans might not be qualitatively different from machines, their unique qualities being seeming instead of real. The discovery that he has been 'programmed not to notice' (p. 499) his artificiality forces Poole to contemplate whether he is merely a puppet whose strings are being pulled by unknown agents. 'Programmed', he contemplates, 'In me somewhere, […] there is a matrix fitted in place, a

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[191] Philip K. Dick, 'The Electric Ant', in *Machines that Think: The Best Science Fiction Stories about Robots and Computers* (see Asimov, Warrick, and Greenberg, above), pp. 495–515 (p. 504). Further references to this short story are given in parenthesis.

grid screen that cuts me off from certain thoughts, certain actions. And forces me into others. I am not free. I never was, but now I know it; that makes it different' (p. 499). In other words, Poole is a machine that has become aware of its own artificiality, and it is this recognition that allows him to attempt to break free of the matrix. As many other protagonists in Dick's fiction, Poole encounters the possibility that 'objective reality is a synthetic construct' (p. 501) created through 'a hypothetical universalization of a multitude of subjective realities' (p. 502). In this way, Dick makes Poole a symbol of mechanized existence through which he defines the relationship between human consciousness and reality: just as the pre-programmed consciousness of an electric ant, human consciousness creates a conditioned, subjective reality instead of offering access to objective reality. Therefore, like the notion that consciousness is a property of the organic as well as the artificial in the analogies of Kurzweil and Moravec, the story makes no qualitative difference between organic and artificial intelligence.

In terms of the problem of free will, in turn, Dick's portrayal of humans as machines implies an interesting paradox. Although human consciousness appears to have been programmed by outside forces, the recognition of this fact simultaneously points to the possibility of moulding reality in accordance to one's will. This is something that occurs to Poole while talking to his wife, Sarah, about the option of cutting the reality tape:

> "Remember years ago when there were — what was it? — twenty or twenty-two TV channels? Before the government shut down the independents?"
> She nodded.
> "What would it looked like," he said, "if this TV set projected all channels onto the cathode ray screen *at the same time*? Could we have distinguished anything, in the mixture?
> "I don't think so."
> "Maybe we could learn to. Learn to be selective; do our own job of perceiving what we wanted to and what we didn't. Think of the possibilities, if our brain could handle twenty images at once; think of the amount of knowledge which could be stored during a given

> period. I wonder if the brain, the human brain —" He broke off. "The human brain couldn't do it," he said presently, reflecting to himself. "But in theory a quasi-organic brain might." (p. 506; emphasis original)

Poole actually succeeds in making changes to his reality (he changes the scenery around him by making new punch-holes onto the tape), but he does not seem to reach his main goal of attaining a vision of 'ultimate and absolute reality' (p. 510). Rather than experiencing the world as it really is, he is merely left puzzled by the question of reality — he is even driven to doubt whether Sarah exists objectively or not (p. 511). Such an ending paints a rather bleak picture of humans' attempts of becoming less mechanized. Even the realization that we are machines is none too obvious, and breaking free from conditioned patterns of thought and behaviour involves the danger of being overwhelmed by reality. Indeed, Poole's consciousness is extinguished after being flooded with a conglomeration of images and sensations. Hence, as the reference to a quasi-organic brain suggests, survival in the information-laden modern world necessitates human-machine mergers in the fashion proposed by post-human thought.

Dick explores this idea in more detail in his novels, of which perhaps the best-known is *Do Androids Dream of Electric Sheep?*. Its protagonist, Rick Deckard, is a bounty-hunter who hunts down androids, robots with human appearance, on behalf of San Francisco Police Department. He is given the task of locating and destroying six dangerous androids that have escaped to the Earth from a space colony on Mars, where humans have migrated in order to escape widespread pollution. For Rick, the successful completion of the assignment holds not only the promise of wealth but also the possibility of climbing the social ladder: he dreams of being able to purchase a sheep, for animals, most of which have been wiped out by the pollution, are considered luxury items testifying to the social standing of their owners.

One of the major ways in which Dick's novel approaches the relationship between humans and machines is the exploration of conceptual oppositions such as empathy versus intelligence, a feature linked to the protagonist's eventual transformation. Rick's method of distinguishing androids from humans consists of administering on suspects a test called the Voigt-Kampff Empathy Test, which measures the ability to react empathetically to situations involving identification with living beings. Noting that androids are unable to react with empathy to his questions, Rick draws the line between them and humans as follows:

> Empathy, evidently, existed only within the human community, whereas intelligence to some degree could be found throughout every phylum and order including the arachnida. For one thing, the emphatic [*sic*] faculty probably required an unimpaired group instinct; a solitary organism, such as a spider, would have no use for it; in fact it would tend to abort a spider's ability to survive. It would make him conscious of the desire to live on the part of his prey. Hence all predators, even highly developed mammals such as cats, would starve.
>
> Empathy, he once had decided, must be limited to herbivores or anyhow omnivores who could depart from a meat diet. Because, ultimately, the emphatic [*sic*] gift blurred the boundaries between hunter and victim, between the successful and the defeated.[192]

Having more in common with insects than with the more social creatures, an android — or 'andy' — is in Rick's view 'like any other machine' (p. 35), being superior to electric animals such as the artificial sheep that Rick keeps only by virtue of its intelligence (p. 37). It is, however, difficult for bounty-hunters to recognize andies because in many cases the new type of android, the Nexus-6, cannot be easily distinguished from humans. This is the

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[192] Philip K. Dick, *Do Androids Dream of Electric Sheep?* (New York: Doubleday, 1968; Orion, 1999), p. 27. Further references to this book are given in parenthesis.

problem from which the novel proceeds to investigate the relationship between humans and machines, suggesting that instead of being stable, the boundary between the two is liable to be blurred.

As the hunt for the escaped andies progresses, this boundary seems to become increasingly vague. Rick develops feelings for the attractive female androids he is supposed to destroy, which gives rise to a conflict between intellect (professional behaviour) and emotion (empathy). In consequence, he notices that some humans are in fact more machine-like in their behaviour and emotional responses than androids. For instance, from Rick's viewpoint the android Rachael Rosen seems to 'have more vitality and desire to live' (p. 81) than his wife, Iran. (Indeed, the novel begins with Rick and Iran discussing how technology allows humans to program themselves in order to experience various emotions; the implication, of course, is that they live in a society in which individuals have become incapable of experiencing meaningful emotions, and need artificial simulation to induce them.) Although he lets his intellectual side dominate his feelings, when meeting Phil Resch, another bounty-hunter, Rick comes to realize that the boundary he has drawn between humans and androids does not accurately model reality. Resch clearly enjoys the process of hunting down androids and destroying them, even to the point of advising Rick to have sex with attractive female androids before killing them as a means of internalizing the idea that love is nothing more than sexual desire that has nothing to do with affection or empathy. As Patricia Warrick observes, Resch functions as a mirror through which Rick eventually realizes that 'he has become transformed into an android-killing machine' (p. 225), thus not being qualitatively different from his victims, who are killers. Therefore, as in the rhetoric of Kurzweil and Moravec as well as in the fiction of Asimov and Clarke, in

Do Androids Dream of Electric Sheep? the underlying logic of co-evolution is based on the figural logic of antimetabole: while machines are becoming more and more human-like, humans display increasingly mechanized behaviour.

In addition to contrasting Rick with the callous Resch, Dick focuses on the boundary between humans and machines through the character of John Isidore. Unlike the coolly calculating Rick, Isidore is a so-called chickenhead, an intellectually inferior yet empathetic mutant, who gives shelter to the android Pris Stratton. In fact, it is through Isidore's point of view that readers are given an alternative angle to the behaviour and actions of the bounty-hunters:

> He had an instinct, glimpsed darkly impression: of something merciless that carried a printed list and a gun, that moved machine-like through the flat, bureaucratic job of killing. A thing without emotions, or even a face; a thing that if killed got replaced immediately by another resembling it. (p. 136)

By creating a comparison between bounty-hunters and androids, the hunters and the hunted, Isidore's point of view foregrounds their similarity as intelligent machines whose primary aim is to survive. Although Pris treats Isidore cruelly, constantly humiliating him and deliberately torturing a spider in front of his eyes, he shows kindness towards her and the two remaining androids that hide from Rick in his apartment. In the light of his unselfish actions, Isidore thus represents compassion towards all forms of life: he makes no distinction between organic and artificial life, claiming that 'even animals — even eels and gophers and snakes and spiders — are sacred' (p. 138).

Ultimately, the change that occurs in Rick's thinking is caused by the discovery of his neglected compassionate self, symbolized by Isidore (Warrick, p. 225). Rick has sex with Rachael but, against the instructions of Resch, does not kill her afterwards. Instead, he admits that although she is not legally alive, she is nevertheless 'an organic entity' (p. 168). In this way, then, Rick's inner transformation is depicted through a reversal of roles: because of his newly found gift of empathy, he lets Rachael go, thus letting the victim prevail. At the end of the novel the reversal is complete, as Rachael kills the real goat on which Rick has spent all the money he has earned by destroying androids.

The process of transformation finally culminates in Rick's fusion with Wilbur Mercer, a religious leader whose system, Mercerism, stresses the importance of grasping the significance of unity and empathy. Not surprisingly, like many other entities in Dick's fiction, Mercer is a mixture of the authentic and the inauthentic: in spite of his appearance as a mythical figure (Mercer is engaged in the Sisyphean task of endlessly climbing up a hill) who voices statements that evidently explain the philosophy underlying Dick's story, he is exposed as an alcoholic ex-actor. Yet, even though Mercer is a fake prophet, the validity of his teachings does not seem to be undermined. When capable of seeing through Mercer's eyes, Rick comes to understand that it is life that ultimately unites seemingly opposite concepts, as there is 'life which we can no longer distinguish; life carefully buried up to its forehead in the carcass of the dead world' (p. 205). Indeed, as if to confirm the validity of Mercer's teachings, Rick finds a toad — an animal believed to be extinct — in the arid sands of the desert, and takes it home in order to claim a substantial reward. Ironically, however, Iran discovers that the toad, like the spider tortured by Pris, is artificial. In spite of the animal's artificiality, the Deckards decide to keep the toad as a pet, a gesture that suggests reconciliation between the organic and the inorganic. 'The electric things', Rick admits, 'have their lives, too. Paltry as those lives are' (p. 208), a statement further emphasizing the idea that life should be understood as a unified whole transgressing man-made boundaries, such as that between humankind and machines. This echoes the reconciliatory efforts evident in Kurzweil's umbrella terms and Moravec's double hierarchy arguments: it is consciousness that ultimately unites biology and technology as the complementary protagonists of co-evolution.

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The dark mood of Philip K. Dick's exploration of the relationship between humankind and its machines is also prevalent in a science fiction sub-genre that focuses exclusively on the phenomenon of virtual reality: cyberpunk. As N. Katherine Hayles has noted, cyberpunk stories typically take place in cyberspace, which protagonists access by linking their minds to computers, thus raising the question about the necessity of embodied experience in high technology environments (*Posthuman*, pp. 35–36). Since such environments are conducive to a pronounced split between mind and body — the former operates in the realm of virtual reality while the latter remains in the physical world — cyberpunk stories take part in the same discussion about the evolutionary direction of humankind as the popularized books of Ray Kurzweil and Hans Moravec.

The question of the mind-body dichotomy is thematized by many classic representatives of the genre, such as William Gibson's so-called Sprawl trilogy. While its famous first part, *Neuromancer*, focuses on the virtual reality exploits of a character named Case, a cyber cowboy who makes his living by illegally entering corporate databases, the second part, *Count Zero*, describes a battle between multinational companies for the ownership of a microchip. The final part of the trilogy, *Mona Lisa Overdrive*, features a number of loosely interlinked stories with themes similar to those in the previous parts.

In *Neuromancer* the protagonist Case is caught stealing from one of his employers, and consequently punished by having his nervous system partially destroyed, which makes him unable to enter cyberspace. However, Case is then given the chance of recovering from his condition, as he is recruited into a team that aims to enter the databanks of large corporations. During his employment Case encounters Wintermute, a potent artificial intelligence that seeks to become a disembodied entity by discarding the hardware in which it is located. With Case's help Wintermute eventually succeeds in the task and rewards its human ally.

As a character Case exemplifies the uneasy co-existence of body and mind in virtual environments. Previously a thief in the fluid world of information patterns, he has had little use for the former, but is now forced to confront the experience of trying to cope with its limitations. 'For Case,' the narrator notes,

who'd lived for the bodiless exultation of cyberspace, it was the Fall. In the bars he'd frequented as a cowboy hotshot, the elite stance involved a certain relaxed contempt for the flesh. The body was meat. Case fell into the prison of his own flesh.[193]

With his nervous system damaged by 'Russian mycotoxin' (p. 12), Case's body is not only metaphorically but also literally a source of anxiety. Moreover, the deal Case makes with Armitage, the shady personality behind the team, also points to the negative connotations of the meat and prison metaphors: in order to prevent him from completing the task

[193] William Gibson, *Neuromancer* (London: Gollancz, 1984; London: HarperCollins, 1995), p. 12. Further references to this book are given in parenthesis.

unsuccessfully, Armitage has toxic sacs planted into Case's arteries, so that in the instance of failure, his condition will deteriorate. Hence, in the technologically sophisticated but dystopian society depicted in the novel it is Case's dependency on his body that ultimately threatens his survival. This raises the question whether bodies are at all needed when life to a considerable extent consists of dealing with electric information and whether in such conditions they could become instruments of control.

The latter question is evident in the case of the cyborg Molly Millions, another member of Armitage's team. In Paris Case goes into a nightclub in which he is supposed to have a rendezvous with Molly but instead of finding her in a particular cubicle, he encounters a girl whom the narrator describes as follows: 'Her eyes were soft and unblinking. Automatic pilot. A neural cutout' (p. 175). The girl is a 'meat puppet' (p. 176), a prostitute whose neural system has been artificially disconnected from her body. Significantly, Molly too has worked as a prostitute before becoming a so-called razorgirl, a combination of a bodyguard and a mercenary. Although successful in her current profession, it is obvious that with its extensive modifications, her body belongs to her employer, just as it used to belong to her previous owner in the brothel. In this respect, then, the prostitute and Molly — as well as Case — are in the same kind of situation: since their bodies are owned by someone else, it is only inside their minds that they possess a degree of freedom.

Therefore, Gibson's portrayal of the society in which Case and Molly live foregrounds the idea that individuals are always controlled and used by someone or something more powerful, as in the case of employees who have their corporation's name tattooed on their bodies and who are 'implanted with advanced microprocessors that [monitor] mutagen levels in the bloodstream' (p. 18). The result of this kind of control is mechanization, a theme directly linked to Gibson's way of describing his characters through references to inert or inorganic objects. For instance, in the second part of the trilogy, Turner, a mercenary who is hired to ensure the defection of an important researcher named Mitchell from one corporation to another, is introduced to a famous actress whose 'blue eyes were inhumanly perfect optical instruments, grown vats in Japan', making her 'both actress and camera'.[194] This resembles the description of a pilot whom the protagonist of the novel, Bobby Newmark, meets:

> Conroy's voice was flat and uninflected, as though he modeled it after a cheap voice chip. His face was broad and white, dead white. His eyes were dark-ringed and hooded, beneath a peroxide thatch combed back from a wide forehead. He wore a black polo shirt and black slacks. (p. 8)

While the actress's mechanization is truly literal — she is a mixture of the organic and the inorganic with her camera eyes — the pilot represents the convergence of humankind and technology at a more metaphorical level, emphasizing especially the ominousness and inhumanity of the process.

It is notable that such inhuman features are found not only in certain types of individuals but also throughout the whole social stratum depicted in the trilogy, suggesting widespread mechanization. The subculture of Gothick, for instance, aims at conveying a sense of lifelessness, as Bobby, the Count Zero of the novel, finds out. Sporting the compulsory 'graveyard pallor' (p. 36) on their 'nearly identical faces', Gothicks remind him of 'a composite creature, slime mold with a jigsaw surface of dark leather and stainless spikes', while a girl Bobby is introduced to watches him 'with mild interest but no flash of

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[194] William Gibson, *Count Zero* (New York: Arbor Books, 1986; New York: Ace Books, 1987), p. 91. Further references to this book are given in parenthesis.

human recognition, as though she were seeing an ad for product she'd heard of but had no intention of buying' (p. 37). In the same way, mechanization is present in the general atmosphere of *Mona Lisa Overdrive*: the stripper Mona, one of the novel's protagonists, notes that the men who watch her

> wore the expression men always wore when they watched you dance, staring real hard but locked up inside themselves at the same time, so their eyes told you nothing at all and their faces, in spite of the sweat, might have been carved from something that only looked like flesh.[195]

In addition to being a stripper, Mona is a prostitute whose boyfriend Eddy is sexually aroused by Mona's stories in which she portrays herself as 'a piece of equipment' her clients '[rent] for half an hour' (p. 35). Such passages create a pervasive sense of mechanization, since Mona describes both herself and those to whose gaze she is subjected in terms suggesting inanimate qualities.

Prevalent mechanization is also indicated by the fact that even those in the highest positions of multinational corporations, the so-called zaibatsus, are more like 'hives with cybernetic memories, vast single organisms, their DNA coded in silicon' (*Neuromancer*, p. 242) than truly individual beings. As in the case of Gothicks, this kind of collective identity clearly makes them appear inhuman:

> Case had always taken it for granted that the real bosses, the kingpins in a given industry, would be both more and less than *people*. […]. He'd always imagined it as a gradual and willing accommodation of the machine, the system, the parent organism. It was the root of the street cool, too, the knowing posture that implied connection, invisible lines up to hidden levels of influence. (*Neuromancer*, p. 243; emphasis original)

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[195] William Gibson, *Mona Lisa Overdrive* (London: Gollancz, 1988; London: HarperCollins, 1995), p. 32. Further references to this book are given in parenthesis.

An illustrative example of a zaibatsu-like entity is the character of the art mogul Josef Virek in *Count Zero*, who commissions Marly Krushkhova to locate the artist behind certain valuable works. Because of his advanced age, Virek has to keep his physical body in a life-preserving tank, and appears to others only through virtual avatars. For this reason, he has been left him in a limbo between life and death. 'I imagine', he describes his own situation, 'that a more fortunate man, or a poorer one, would have been allowed to die at last, or be coded at the core of some bit of hardware' (p. 16). In other words, although he is an extremely wealthy and powerful individual, Virek is at the mercy of the corporate machine, which uses him as a financial resource. The irony of it is that he has become a part of the machine he has created, giving life to immense wealth that appears to have 'a life of its own. Perhaps a will of its own' (p. 74). In the same way, the head of the Maas-Neotek company in *Mona Lisa Overdrive* resembles an inanimate object with 'his eyes flat and bright, like the eyes of a painted doll' (p. 8). Such instances blur the boundary between the organic and the inorganic, and draw attention to the reciprocal logic of co-evolution: while organic beings are becoming increasingly machine-like, inorganic phenomena such as multinational corporations and their wealth appear to have become alive.

Conversely, the trilogy at times also foregrounds the highly intimate nature of co-evolution by comparing the inorganic to the organic. Consider, for instance, Gibson's portrayal of the vehicle in which Turner and Mitchell's daughter escape from their pursuers in *Count Zero*:

> The plane was smart, smart as any dog, with its hard-wired instincts of concealment. […]. The plane crept into deep green shadow and sank on its knees, its airframe whining and creaking as it flattened itself, belly down, into loam and granite like a manta ray into sand. (p. 125)

The passage uses several metaphors and similes to suggest similarity between the plane and an intelligent being, such as an animal. After the plane has camouflaged itself in the forest, the narrator again turns to the mechanical qualities of animate beings, as the sleeping Turner comes 'awake like a machine, eyes opening, vision plugged in' (p. 125), and a while later sees a crow whose feathered wings resemble 'black mechanical fingers' (p. 127). By its comparisons between the inorganic and the organic as well as the organic and the inorganic, the scene thus emphasizes the reciprocal nature of co-evolution.

As in the visions of Kurzweil and Moravec, this process of convergence culminates in the separation of mind from body. At the end of *Neuromancer* we learn that the aim of Marie-France Tessier, who with her husband John Harness Ashpool runs the powerful corporate family of Tessier-Ashpool, was to initiate 'a symbiotic relationship' (p. 271) between humans and artificial intelligence that would result in their fusion, allowing the members of the family to become immortal as 'units of a larger entity' (p. 271). This plan, however, comes to a halt as John kills Marie-France in order to prevent the fusion. Wintermute, one of the two artificial intelligences created by the family, nevertheless continues implementing the plan with the intention of becoming free of its own metaphorical body: its hardware. In order to reach this goal, Wintermute has to undergo the process of merging with something that possesses qualities it is not equipped with. It finds them in its sister machine, Neuromancer, which has developed a distinct 'personality' (p. 315). By uniting with Neuromancer, then, Wintermute becomes something more than a machine.

Hence, the process whereby artificial intelligence becomes independent of its physical basis and enters virtual reality as a disembodied entity clearly resembles the process that both corporations and individuals undergo, as their existence becomes less and less dependent on matter. Indeed, Dixie Flatline, a ROM construct living in the cyberspace, draws a comparison between Wintermute and corporations, noting, ‘I can’t see how you’d distinguish, say, between a move the parent company makes, and some move the AI makes on its own’ (p. 159). In *Mona Lisa Overdrive* the narrator in turn informs readers that ‘major corporations were entirely independent of the human beings who composed the body corporate’ (p. 157). In the case of individual characters, seeking to escape his confinement to ‘the four hundred kilograms of rioting cells’ in a vat, Josef Virek sees disembodiment as ‘the next stage of evolution’ (p. 219), and for this purpose aims to ‘code his personality’ into the virtual ‘fabric’ (p. 227) of Wintermute. In this way, Gibson once again points to the fundamental logic of co-evolution: while artificial intelligence seeks contact with something that possesses distinctive human qualities, humans seek to fuse with artificial intelligence in order to become immortal. In Virek’s case evolution into a disembodied form is perceived as a necessity from the viewpoint of his corporation, because his death would make ‘his business interests […] lack a logical focus’ (p. 101).

Mona Lisa Overdrive returns to the theme of co-evolution by describing it in terms of a self-propelling process. At the end of the trilogy cyberspace has become populated with disembodied entities, one of whom illustrates the process that has led to the birth of intelligent machines to a human character:

> In the hard wind of images, Angie watches the evolution of machine-intelligence: stone circles, steam-driven looms, a clicking brass forest of pawls and escapements, vacuum caught in blown glass, electronic hearthglow through hair-fine filaments, vast arrays of tubes and switches decoding messages encrypted by other machines … The fragile, short-lived tubes compact themselves, become transistors; circuits integrate, compact themselves into silicon …
>
> Silicon approaches certain functional limits — (p. 263)

The end of the passage uses a gradatio-like structure to portray the process as various artificial objects giving birth to similar yet more complex items, seemingly echoing Kurzweil’s and Moravec’s notion of technological evolution as a self-propelling progress towards increasingly sophisticated forms of machinery. It is significant that the artificial intelligence appearing in the novel is named Continuity: the ultimate aim of technology is to give birth to more technology in the manner of organic beings that seek to ensure the survival of their genes. Fittingly, a disembodied intelligence goes on to reveal the primary function of Continuity in appropriately tautological terms. ‘Continuity is continuity’, it states, ‘Continuity is Continuity’s job …’ (p. 265) — note how closely Gibson’s syntactic formulation resembles the epanalepsis used in Kurzweil’s statement about technology begetting new technology.

While co-evolution thus promises independence for machines in the Sprawl trilogy, it is evident that Gibson’s flesh-and-blood protagonists are — for better or worse — bound to their bodies. The ambiguity of the situation is reflected by the fact that even if the bodies of Case and Molly are owned by their employers, it is nevertheless the embodied experience that continues to make life meaningful. Making love to Molly, Case notes this:

> There was a strength that ran in her, something he’d known in Night City and held there, been held by it, held for a while away from time and death, from the relentless Street that hunted them all. It was a place he’d known before; not everyone could take him there, and somehow he always managed to forget it. Something he’d found and lost so many times. It belonged, he knew — he remembered — as she pulled him down, to the meat, the flesh the cowboys mocked. It was a vast thing, beyond knowing, a sea of information coded in spiral and pheromone, infinite intricacy that only the body, in its strong blind way, could ever read. (pp. 284–85)

Significantly, the passage shows that instead of being merely the prison-house of mind, the body does after all have a positive role to play in the lives of the characters. The metaphor of *a sea of information coded in spiral and pheromone* clearly juxtaposes physical and virtual existence, suggesting that like mind, the human body is a gateway to other realities and therefore a potential instrument of liberation — it is just the increasing mechanization of society that causes us to forget this fact.

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In the fiction discussed above the reconfiguration of the human-machine dichotomy mainly takes place through various types of characterization. For instance, Isaac Asimov's robot stories pair humans and robots for comparison, antimetabolically foregrounding the mechanical traits of human characters and the human traits of robots. In this way, they acknowledge the two as equally conscious beings in spite of the fact that they have different skills. Arthur C. Clarke's space odyssey tetralogy portrays co-evolution in the same manner, but also emphasizes through its structure the notion that it is driven by the incremental logic of post-humanism. The culmination of this process is represented by the character of Halman, whose name is basically an oxymoron indicative of the fusion of the organic and the inorganic. Likewise, Philip K. Dick's fiction portrays this blurring of the boundaries through characterization, with his human characters resembling machines and his machines resembling humans. Finally, the cyberpunk novels of William Gibson similarly reverse the traits of humans and machines through their characterization and figures of comparison, while presenting the idea that technology gives birth to increasingly sophisticated technology in a self-sustaining fashion.

5.4 Computers, Information Technology, and Artificial Intelligence: Conclusion

In this chapter I have discussed the representation of computer and information technology in contemporary popular science writing and literature. I focused especially on questions that developments in the field of artificial intelligence have raised during the latter half of the twentieth century and that are becoming increasingly acute as information technology continues to become more and more sophisticated. My point of departure for the discussion was the claim that the development of artificial intelligence is intimately linked to the future of human evolution, as the artificial and the organic are joined in a process of co-evolution. Because the two shape each other in ways that may be quite unpredictable, it is obvious that technological co-evolution, with artificial intelligence representing just one of its various manifestations, affects our understanding of human identity by questioning many basic assumptions that we have of what N. Katherine Hayles calls the liberal humanist subject. At the same time Hayles's post-human subjectivity draws our attention to questions of machine identity, since co-evolution also concerns our understanding of technology.

Given that the issue of artificial intelligence is closely linked to our definitions of what it means to be human, it is clear that it is a subject that elicits widely differing responses. For instance, Joseph Weizenbaum's *Computer Power and Human Reason* and Roger Penrose's *The Emperor's New Mind* advocate the view that the gap between human and machine intelligence will never be closed, as human mental faculties and emotions cannot be taught to computers by translating them into the language of algorithms. Both Weizenbaum and Penrose maintain that human consciousness contains elements that are uniquely human, although their argumentation proceeds in different ways. Weizenbaum's way of drawing a strong analogy between the unconscious and the unknown — whether the latter is compared to the observation of the subatomic world or to a stormy sea — represents a view that attempts to preserve the autonomy of Hayles's liberal humanist self by suggesting that human knowledge is bound to remain incomplete. Penrose in turn reconfigures the relationship between the conscious and the unconscious parts of mind, and in strict terms proposes that it is in fact the processes of the former that do not yield to accurate modelling on computers. None the less, like that of Weizenbaum, his argument aims to preserve the uniqueness of the self by pointing to the inevitable incompleteness of knowledge, as well as to the notion of body and mind forming an undivided whole.

For supporters of the strong AI theory, however, there are no such obstacles — or, if there are, they are merely temporary problems. In the post-human visions of Ray Kurzweil's *The Age of Spiritual Machines* and Hans Moravec's *Mind Children* the boundary between the artificial and the organic constitutes a false distinction, being merely an indicator of our prejudice against technological development. In their view artificial intelligence will develop much like animals and humans have evolved, with the border between man and machine eventually vanishing, as machines pass the stage of co-evolution and enter a period of wholly independent existence in the near future. Employing figurative language in similar ways, Kurzweil and Moravec envision the co-evolution of humankind and technology as a self-propelling incremental series that extends far beyond the current forms of both, and foreground the reciprocal nature of their relationship in a manner suggested by the logic of antimetabole. Their analogies help buttress the idea that humans — as well as other forms of organic life — and machines are essentially similar in the sense that their identities, or selves, stem from patterns of information rather than matter. In this way, Kurzweil and Moravec align their visions with the post-human redefinition of the self as a historical and social construction, while their separation of mind from body through the assertive use of antithesis distances them from the more moderate configurations by strongly questioning the need for physical embodiment.

In fiction too it is possible to detect different kinds of responses to the question of machine intelligence. While writers such as Isaac Asimov and Arthur C. Clarke envision co-evolution in terms that anticipate Kurzweil and Moravec, testifying to the fact that just as the rhetoric of popular science is often reflected in literature, so the underlying logic of literary portrayals is evident in the rhetoric of popularizations, Neal Stephenson's *Snow Crash* and Richard Powers's *Galatea 2.2* point to qualitative differences between humans and machines. In doing so, Asimov's robot stories and Clarke's tetralogy foreground the reciprocal logic of co-evolution: while their robots and computers display increasingly human-like characteristics, their human characters often behave like machines. Stephenson and Powers also portray co-evolution in their stories but resist the urge to erase difference, the former through his depiction of the negative effects of such a merger, the latter through his emphasis on the importance of embodied experience. While humankind and machines may continue to co-evolve in the future, having many significant features in common, the latter will never experience the world directly because the mysterious mental processes of the former cannot be revealed in their entirety. In the science fiction of Philip K. Dick and William Gibson, in turn, the blurring of the boundaries between the artificial and the organic is a more or less inevitable process portrayed in rather dark tones. While Dick's work draws our attention to the mechanization of humankind and the human-like qualities of machines by pointing to the falsity of the distinction between organic and artificial life, Gibson's trilogy depicts a dystopian future in which the liberation of artificial intelligence coincides the economic and technological subjugation of the human body.

All in all, as in the case of evolutionary biology, representations such as the ones studied above testify to the ambiguous state of AI research at the present moment. Just as Dawkinsian neo-Darwinism and the new biology emphasize different qualities in the behaviour of organisms, so there is a clash of views between those who argue that humans and machines are and will remain qualitatively different and those who only detect a quantitative difference. As regards the topic of identity, what is at stake is the question about the uniqueness of the human species: while the complexity surrounding the co-evolution of humankind and its machines prevents us from giving a clear-cut answer to it, it is certain that the meanings that popular science writing and literature attach to co-evolution guide our understanding of ourselves, even in part contributing to the culturally determined construction of the self.

6. Conclusions

In my thesis I have tried to extensively illuminate a few of the myriad aspects of the relationship between the two cultures of science and literature. Firstly, although the notion of science as a partly rhetoric enterprise has been established as an unquestionable fact by recent decades of social and cultural studies, the vast scope of the topic has ensured that many of its important facets have not been adequately explored. In the case of the stylistic and argumentative elements of rhetoric of science, critics have — for a perfectly good reason — often observed how metaphor functions as a tool of invention and illustration in scientific arguments without considering the roles of other figures of speech, consequently neglecting the others. However, using contemporary popular science writing as an example, I have shown that the warehouse of figures writers frequently visit also contains a considerable amount of other tools whose rhetorical importance cannot be underestimated. Antimetabole, alliteration, anaphora, antithesis, characterismus, coenotes, effictio, epanalepsis, epistrophe, ethopoeia, incrementum, gradatio, oxymoron, ploche, simile, and synoeciosis — all appear alongside metaphor as its usually unrecognized and unnamed companions. Rarely strictly stylistic or strictly argumentative in their function, they habitually epitomize the philosophy underlying the writer's argument while establishing a certain kind of logic that guides its development.

Secondly, focusing on the representation of science in literature, I have discussed how the world of letters has dealt with scientific ideas, concepts, and theories. In doing so, I have demonstrated how literature has contributed to the creation of a cultural science — a science that through a process of linguistic signification simultaneously both produces and responds to the various meanings that our culture attributes to science. I argued that this process reveals certain meeting points for science and literature in which influence is reciprocal rather than unidirectional: while figurative language used by popular science writing is often implicit in literature by virtue of pointing to the underlying philosophy of literary works and guiding the overall ‘logic’ of representation, such devices greatly enhance the ‘literary’ qualities of popular representations of science. Moreover, I analysed how the process of signification gives rise to the two field’s responses to specific shared topics or discourses, of which especially knowledge and identity emerge as the most prominent ones.

In my discussion I showed in practice how cultural science is created in the case of the natural sciences. Beginning with popular accounts of the new physics of relativity theory and quantum physics, I observed that they tend to rely on figures of speech that foreground dynamic interaction and complementarity, such as antimetabole and synoeciosis. In fiction and drama appropriating ideas from the same field, formal features emphasize the significance of the same concepts for our understanding of knowledge and identity. In terms of their shared topics, both popular science and literature in this way stress the notion that human knowledge is fundamentally uncertain and partial and that instead of consisting of opposite qualities, the self is a totality of complementary traits and qualities.

Dealing with the cultural aspects of chaos theory and complexity, the second part of the discussion showed how popular science writing and literature use the field’s insights in order to build a bridge between nature and humakind. In doing so, popular science seeks to overcome various dichotomies, and this attempt is reflected in the writers’ rhetoric. For instance, seemingly opposite concepts are shown to be mutually inclusive parts of a more general third concept, different types of series emphasize that the difference between opposites is quantitative rather than qualitative, and antimetabole links opposites together as a means of showing the complementary nature of their relationship. Narrative fiction and drama build a similar kind of bridge by using formal elements that foreground the unification of chaos and order, the importance of holism, and the world's fundamental unpredictability. Through chaos theory and the study of complex phenomena, science and literature thus explore the shared topic of knowledge. Encouraging a distinctively holistic approach, they suggest that while the complexity of the world prevents us from knowing everything in complete detail, we can nevertheless observe how the parts comprising nature's whole are linked to each other in a way that is meaningful from human point of view.

In my discussion of evolutionary biology I studied the conflict between the neo-Darwinist notion of genes as the selfish primary units of natural selection and the theories of the new biology that regard evolution as driven by catastrophic change and emphasize cooperation rather than struggle between the parts of life's totality. The formal devices of both popular science writing and literature point to the kind of ambiguity that characterizes our understanding of human identity. For instance, whereas the metaphors and analogies of neo-Darwinism help portray organisms as self-interested players, the new biology often employs various kinds of argumentative series, all-inclusive umbrella terms, synoeciosis, and metaphor in order to highlight the importance of cooperative behaviour for evolution. In fiction the same dichotomy emerges in conjunction with themes that set individuals against their genetic inheritance or study them in a larger evolutionary context. However, although neo-Darwinism and the new biology differ from each other in regard to the fundamental nature of organisms, they are nevertheless to a considerable extent non-anthropocentric in their insistence that humankind does not necessarily constitute the pinnacle of evolution.

Finally, I considered a recent debate in the field of computer and information technology by focusing on views against and for the strong position of artificial intelligence. The rhetoric of writers in the former group is mainly built on analogies between human consciousness and phenomena that appear to defy the totality of description or representation. The latter group also uses analogy as an important argumentative tool, but to the opposite end of questioning and blurring the boundary between humans and machines. In addition, a characteristic rhetorical feature in the arguments of this group is the use of series that make organic intelligence the precursor of the artificial kind and strongly antithetical formulations that seek to separate mind from body. In fiction too it is possible to separate — if not always clearly — narratives that draw a line between human and computer intelligence from the ones that do not. For our understanding of human identity in a possibly post-human future, both kinds of narratives seem to have their value: while the former acknowledge the intimate nature of co-evolution without proposing that computers could develop mental lives comparable to those of their organic creators, the latter offer exciting speculative possibilities for the reconfiguration of the human by suggesting a fusion of the organic and the inorganic.

All in all, my discussion concerning the use of figurative language in contemporary science writing and the representation of science in literature yields the following conclusions:

1. Popular science writing habitually employs a wide range of figures of speech, testifying to their crucial role in the art of persuasion.
2. Through their form the figures of popular science often epitomize the philosophy or ideology of writers' arguments, thus creating a strong link between the form and the content.
3. In their role as epitomes such figures resonate with literary representations of science, which, like popular science writing, explore the human relevance of science by giving culturally determined meanings to scientific ideas.
4. Rhetoric of popular science writers and representations of science in literature constitute two interlinked aspects of cultural science by contributing to the treatment of shared topics, such as knowledge and identity.

These conclusions should by no means be understood to suggest that rhetoric of popular science writing is largely reducible to its figurative language; they merely show that such an element has a significant role in arguments aimed at non-specialist audiences. Moreover, they do not suggest that the links between literature and science should be sought by perusing only the relationship between rhetoric and literary representation. Rather, my purpose has been to study only one of many possible links, charting the numerous instances in which it emerges.

Another thing that the above results should not suggest is that popular science writing and literature are more or less similar in terms of their employment of rhetoric and representation. Even though their ways of using language often overlap in this respect, it is quite evident that there are important differences as well. For instance, figures of speech such as metonymy, synecdoche, and irony — three of Vico's four tropes — do not seem to have any kind of function in the arguments of popular science writing. (Further study could better account for their absence, but one might hazard the guess that irony would probably undermine the credibility of arguments and that there would appear no need to describe things either through association (metonymy) or on the basis of the part-whole relationship (synecdoche), since such descriptions might obscure the clarity of communication.) In contrast, literature seems to make less selective use of figures. This might be explained by the fact that in literature dealing with scientific topics, writers often explain them to readers in the manner of popular science authors (exposition) — thus using the recurring tropes of popular science — while also using tropes characteristic of literature, such as irony, metonomy, and synecdoche. However, as this is a subject matter I did not endeavour to include in my discussion, further research is needed before any decisive conclusions can be drawn concerning such differences.

At the end of 1.2 I pointed out that certain kinds of objections might be made against the way in which I have conducted my analysis of the subject. However, given the aim of my thesis, I do feel I have accomplished what I set out to do. Rather than pointing to the possible shortcomings of my work, then, the hypothetical objections listed in the introduction — and there may be others — might suggest possible avenues for future studies in the fields of rhetoric of science and science-literature criticism. It is perhaps needless to list related research questions here, as the possibilities are so numerous and the interested reader will find suggestions concerning them in the critical works mentioned in the introduction but, generally speaking, topics such as the new technologies (especially technologies dealing with biology and information systems), discourses surrounding the concept of the post-human, and the ideological and socio-political contexts of recent scientific theories are among the ones that at the present moment call for substantial critical attention both in rhetoric of science and the representation of scientific ideas in literature.

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