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In Midstream: Literary Structures in Nineteenth-Century Scientific Writings

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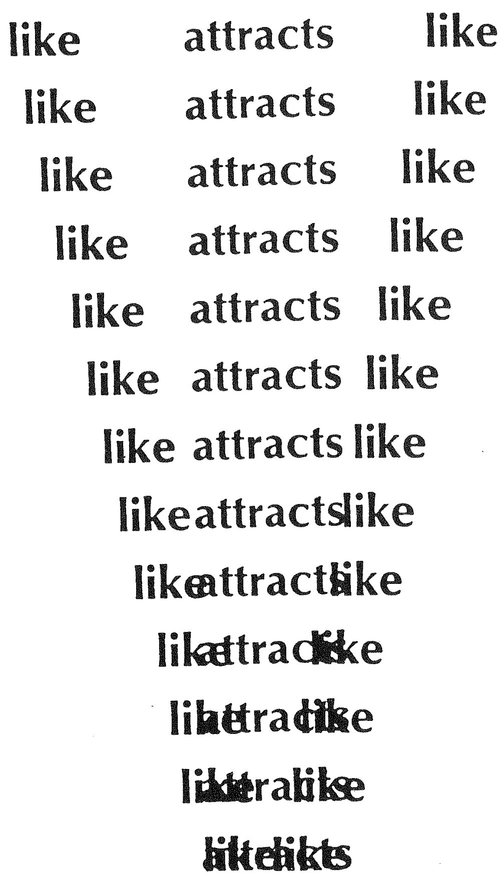

-"Like Attracts Like"-
-Emmett Williams-

Thesis submitted for the Master of Arts Research Degre (mag.art.).

Supervisor: Per Dahl, Department of Comparative Literature, University of Aarhus.

This dissertation contains approximately 318.000 characters (excluding the bibliography), equivalent to approximately 133 normal pages (2400 characters per page). This text is typeset

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Introduction

> "It has been said that science divorces itself from literature; but the statement, like so many others, arises from lack of knowledge [...] Where among modern writers can you find their [the scientists'] superiors in clearness and vigour of literary style? Science desires not isolation, but freely combines with every effort towards the bettering of man's estate."
>
> John Tyndall *Belfast Address*, 1874

"On Climate, Cars, and Literary Theory" is the title of an interesting article found the October 2008 issue of the scientific journal *Technology and Culture*.[1] The article is written by the professor of comparative literature, Karen Pinkus. I found this article by chance, when I browsed through different academic journals on the history of science. This coincidence is a good illustration of the fact that literature, and just as importantly, literary history are slowly becoming integrated parts of the scholarly discipline of history of science. In her article, Pinkus sets out to prove that even dissimilar objects like cars and climate changes can be viewed from a perspective of literary history and criticism. Quite interestingly, Pinkus' article differs from many other works on the connections between literature and science and technology that I have come across in my research: Pinkus' article does not mention C. P. Snow (1905–1980) and the notion of 'two cultures'.

In his influential *Rede Lecture* from 1959, the scientist and literary author Snow argued that the communication between the sciences and the humanities had suffered a serious breakdown. Since the last part of the nineteenth century, the natural sciences had become increasingly specialised and professional, and the texts and language of the sciences had equally become somewhat obscure for non-scientists. Although my dissertation is not directly concerned with Snow and the concept of the two cultures, it is still an undeniable component when dealing with the interrelations between literature and science. Snow's heritage still shines through in the different outlooks on the nature of science which I will investigate further in Chapter Two. The concept of the two cultures is relevant in two aspects of this dissertation: Firstly, in the nineteenth century, the

[1] Pinkus 2008.

relationship between science and the arts was far closer than in the twentieth and twenty-first centuries. Secondly, the differences between science and the arts are important when dealing with the writers, who today are occupied with the relationship between literature and science. Most books on the relations between science and literature mention Snow and the two cultures. Likewise, these works display awareness about the differences and similarities between science and the arts.

Thesis of the Dissertation

This dissertation offers an exploratory view of the relationship between literature and science, focusing on how nineteenth-century scientific writings employed literary elements. The structural framework of the dissertation is centred on the analyses of nineteenth-century scientific writings and the usage of literary elements in the scientific texts. Most studies on the relations between literature and science investigate how literary authors have incorporated scientific theories, ideas and concepts into their works of fiction. Moreover, some — but considerably less — attention has been devoted to exploring the influence of literature upon scientific writings. But to the best of my knowledge, no systematic investigation of how the literary elements are employed in scientific writings has been undertaken.

In this dissertation, I use a case study of nineteenth-century scientific texts on evolutionary theory, to establish a literary analytical model informed by the existing analyses of the connections between literature and science. Much of the existing scholarship in the field has focused on evolutionary theory and especially the works of Charles Darwin (1809–1882). Therefore, this case is a well-substantiated basis from which I have sought to create an analytical model. The central discussions of the dissertation fall in two parts. The main thrust will be centred on the construction of the analytical model and its embedding within the existing scholarship. A second part will then evaluate whether the model only fits the particular case of Darwin and evolutionary theory, or if it can be treated as a more general analytical model fitting other cases from the nineteenth century. Thus, in order to examine to which extent the analyses drawn from the Darwin-case represent a general tendency of nineteenth-century scientific writings, I will include a second case study discussing thermodynamics based on texts by (amongst others) James Clerk Maxwell (1831–1879).

The Structure of the Dissertation

This dissertation consists of four main chapters: The first chapter sets the historical scene of the nineteenth century emphasising the general scientific developments and describing how science and literature interplayed in the period. Chapter Two presents an overview and an analysis of the so-called 'field of literature and science' i.e. the writers and works dealing with the connections between literature and science (see definition below). In addition, Chapter Two includes a view of the fundamental conflict between the literary critics and the historians of science writing within the field, including their outlooks on the role of literature in relation to science.

In Chapter Three, an investigation of the case of Darwin and evolutionary theory is carried out and the analytical model for analysing the role of literature in scientific writings is laid out in detail. The case of Darwin and evolutionary theory is the most widely analysed case within the field of literature and science, and analyses of that case will be examined in the chapter in order to discuss which elements are most prolific to use in the analytical model. Hence, my analytical model will outline a concrete textual analysis model for exploring scientific texts. It is informed by historical investigations into the specific case of Darwin and evolutionary theory. In Chapter Four, the second case study on thermodynamics serves as the basis for discussing whether the analytical model created from the Darwin-case can also function with respects to the case of thermodynamics.

The first two chapters are each structured around the two components of historical description of the central themes and methodological reflexion. Hence, Chapter One contains a description of the scientific development in the nineteenth century as well as an analysis of the relationship between science and literature in the period. Similarly, Chapter Two features a description of the historical development and establishing of the field of literature and science as well as an analysis of the basic conflicts between historians of science and literary critics over the view of the relations between literature and science. This duality between historical description and critical analysis is also maintained in the two case studies presented in the two subsequent chapters, although it is not as systematically expressed. I have found it necessary to include all of these historical descriptions and more complex methodological analyses, because the dissertation presents a general analytical model founded in the history of science for which a thoroughgoing structure of description and analysis is indispensable.

Definitions

In the following, I will briefly define some of the key concepts, theories and terms used throughout the dissertation which may require initial clarification. The dissertation deals with complex interrelations between two different kinds of expressions, literary and scientific expression, as well as two different bodies of theory represented by the history of science and literary criticism, respectively. Therefore, it is important to understand how these elements are positioned within the framework. Here, I will take a closer look at three central elements of the dissertation, namely the definition of the field of literature and science, the definition of the scientific text, and lastly a look at the definition of literary elements.

This dissertation revolves around the field of literature and science which is also sometimes called the literary history of science. Since the 1960s, both literary critics and historians of science have taken an interest in the relations between science and literature, albeit with different approaches. In this dissertation, I use the expression 'the field of literature and science' as a joint term for writers interested in the connections between literature and science with their emphasis on constructivist approaches. Furthermore, I employ the terms 'literary critics' and 'historians of science' as general notions for particular views on the relations between literature and science. That is, when the term 'literary critics' is used, it refers to a position emphasising literary theory in relation to the connections between literature and science. It is not necessarily restricted to the profession of literary critics, since some historians of science will take up the position of literary criticism. Thus, the terms 'literary critics' and 'literary criticism' are to be understood broadly and include both literary history and theory. Similarly, the group of 'historians of science' is also meant to include scientists writing on the subject.

The field of literature and science is thus quite heterogeneous and complex, and in this dissertation I only focus on a subset of the theories and approaches present in the field (which are unpacked in Chapter Two). A number of theorists writing within the field of literature and science have discussed the very nature of the field and the possibility of a truly interdisciplinary approach. For instance, Katherine Hayles' take on the field resonates with my own view. She writes:

> What does it mean, then, to posit a theory about literature and science? To answer this question, one would have to presuppose a set of disciplinary practices which constitute literature and science of its own. Supposing that such distinctive practices exist [...] the resulting 'theory' will be different from theories about literature and theories about science. It will not, however, be a meta-theory capable of subsuming theories in other disciplines it surveys. The only hope for a truly interdisciplinary theory, it seems to me, is a 'theory' about the impossibility of creating a theory that will not be implicated in disciplinary practices.[2]

Thus, according to Hayles, a truly interdisciplinary theory encompassing literary theory and a theory based on the history of science is not possible, and on this I agree. It is therefore not the purpose of this dissertation to suggest such an interdisciplinary theory capable of uniting the approaches of science and literature. Instead, I wish to construct and discuss a model that will be designated a particular time period and science.

For the purpose of this dissertation, it is also important to define the concepts of science, literature and scientific writings. The words 'science' and 'scientists' in this dissertation correspond to the natural sciences and the practitioners of these.[3] Hence,

[2] Hayles 1990b, p. 213.

[3] The natural sciences of the nineteenth century included astronomy, biology, chemistry, physics and the earth sciences, see Chapter One.

'science' is taken in a narrow sense and does not include for instance history or the cultural sciences. As a rule, the term literature refers exclusively to fiction unless otherwise stated.

The scientific texts, themselves, also need further clarification. In my analyses, I have chosen to focus mainly on popular scientific writings and not professional scientific writings.[4] Therefore, Chapter One includes a detailed account of the development of the genre of popular science as opposed to the professional scientific writings in a nineteenth century context. However, it is not the aim of this dissertation to provide a characterisation of the scientific movements illustrated by the popular scientific texts. Instead, the texts analysed in this dissertation are chosen because they illustrate the complex relations between science and literature. In particular, the two case studies chosen, evolutionary theory and thermodynamics, have been chosen because these cases are central to the scholarship within the field of literature and science.

The popular science articles of the nineteenth century are far more 'literary' in style than most professional scientific texts. This is also the case with popular science articles today, when authors are keenly aware that they have to make the text reader-friendly in ways that are not customary in the highly technical professional scientific writings. When the nineteenth-century scientists had to communicate a complex scientific theory to the general reader through their popular articles, they often chose to do so by elaborate narrative structures, storylines and tropes. In the popular science texts, the scientists made use of the literary language, including tropes and narratives. They did so in order to embed their scientific theory in a constructed closed story presenting a particular view of the world, as will be discussed in Chapter Three.

The term 'literary element' is employed throughout this dissertation to capture such elements of expression. In this context, the definition of the term is broad, meaning that the term covers narrative structures, the roles of author and narrator and linguistic components including tropes. Similarly, I have chosen to use the word 'tropes' only as a common term for the linguistic figures that are relevant to the case studies in the dissertation. Hence, tropes like hyperbole and irony will not be regarded in the dissertation because they have not played a role in the writings on nineteenth-century scientific writings.

Demarcations of the Dissertation

When dealing with the complex relationship between science and literature, I have come to see a number of challenges concerning the demarcation and the treatment of specific elements. In particular, it is important for me to make clear which forms of literature and science that will be dealt with in this dissertation.

[4]There are a few exceptions to this, hence certain texts by MAXWELL analysed in Chapter Four were not specifically written as popular science texts (for instance the excerpt from MAXWELL's work *Theory of Heat*). However, the passages I have chosen to focus on, I would argue, could be read by the general reader and are similar to other popular science writings from the period.

Whether one sets out to investigate how science makes use of literature or the other way round, the nineteenth century is a very varied an exciting time period to focus on. Science and science communication prospered and developed throughout the nineteenth century. In the middle of the nineteenth century a shift occurred in the genre of scientific texts. With a key work like CHARLES LYELL's (1797–1875) *Principles of Geology* (1830-1833), the experiments and observations became a bigger part of the construction of the scientific texts leading up to the positivistic movements in the later half of the century.[5] At the same time, theories — such as thermodynamics and evolutionary theory — came into being, and these were not based on concrete empirical evidence and experiments.

In many other respects, these two sets of theories were quite opposite. DARWIN and other evolutionary theorists argued for the continuous evolution of species towards something greater. Contrary to this continuous evolution, thermodynamics included the theory of an abrupt 'heat death' which would bring an end to the world. What these two theories have in common, however, is that they were both developed in the middle of the 1850s, mostly in Great Britain, and the scientists of these two fields benefitted from using literary elements to convey their theories.

As mentioned, the nineteenth century is also rich on examples of literary works incorporating science including thermodynamics and evolutionary theory. I have chosen only briefly to take these works into consideration although GEORGE ELIOT's (1819–1880) *Middlemarch* is dealt with in more detail, because her work bears many parallels to some of the works by evolutionary theorists. But references to the fictional works in this dissertation will be made only to accentuate the literary components in the scientific works. Thus, they will not be subjected to individual analyses themselves.

A Note on the Works on Literature and Science

The number of works on the connections between literature and science has increased over the past decades. In Chapter Two, I will introduce some of the works central for this dissertation, but in this section I take a brief look at some of the other works that have been written on the subject.

There are different types of surveys on the interrelations between literature and science. Most books and articles on the subject deal with a particular case study or a particular time period.[6] Other works focus on the development in the relation between literature and science in a longer historical context. And lastly, there are works that take a starting point in specific theories. For the purpose of this dissertation, I have for the most part looked at studies focusing exclusively on the nineteenth century and not specific topics. But in order to illustrate the growing interest in the field, I have chosen to briefly mention a couple of works central to the subject of literature and science:

[5] Otis 2002, pp. xviii–xx.

[6] In her essay "Literature and the Modern Physical Sciences", GOSSIN lists many of the most important works on literature and science divided according to the different sciences (Gossin 2002, pp. 10–17).

The nineteenth century and case studies from that period represent most of the books and articles on literature and science. However, the period around 1900 is also a well-researched period, especially when dealing with the biological sciences, quantum mechanics and information theory — the books *Networking: Communicating with Bodies and Machines in the Nineteenth Century* (2001) and *Membranes: Metaphors of Invasion in Nineteenth-century Literature, Science, and Politics* (2000) both by LAURA OTIS are examples of this. The historical development in the relationship between literature and science has also been dealt with in a number of books and articles. One of the first concrete works treating literature and science was also a view on the historical development, namely IFOR EVANS' *Literature and Science* from 1954 which covers the historical relations between science and literature since the renaissance.[7]

In the 1990s, a new theory attempting to unite literature and science formed. The so-called Literary Darwinism views literature as an expression of human biology. Books like *Evolution and Literary Theory* (1994) and *Literary Darwinism* (2004) both by JOSEPH CARROLL and most recently JONATHAN GOTTSCHALL'S *Evolution, Violence, and the World of Home* (2008) all investigate how fundamental biological and evolutionary human characteristics play a role in literary works through time.[8] Another theoretical approach to literature and science is found in IRA LIVINGSTON'S *Between Science and Literature an Introduction to Autopoetics* (2006), where LIVINGSTON combines approaches from disciplines spanning from philosophy to sociology in order to investigate the relation between literature and science.[9] Both of these approaches offer new outlooks on the interrelations between literature and science.

Lastly, I also want briefly to draw attention to a number of comprehensive anthologies which include scientific texts, poetry and excerpt from novels and short stories showing the connections between literature and science. Three extensive anthologies are *Songs from Unsung Worlds* edited by BONNIE BILYEU GORDON (1985), *A Literary Companion to Science* edited by WALTER GRATZER (1989) and *The Twain Meet — The Physical Sciences and Poets* (1989) by NOOJIN WALKER and **Walker**[???] from which the mid-twentieth-century experimental poem used as cover illustration of this dissertation is taken.[10]

However, the works mentioned in this chapter constitute only a fragment of the works written on the subject and although I have tried to be comprehensive, the books and articles referred to in this dissertation also only represent a fragment of what has been written within this exciting and expanding field.

[7] Otis 2001; Otis 2000; Evans 1954.

[8] The article by PINKUS mentioned above can be seen as an following some of the trends in the Literary Darwinism Movement. I will return briefly to the Literary Darwinism Movement in my conclusion, Chapter Five.

[9] Carroll 1994; Carroll 2004; Gottschall 2008; Livingston 2006.

[10] Gordon 1985; Gratzer 1989; Walker and Walker 1989.

Chapter One

Defining Science and Literature in the Victorian Period

> "[T]he view now held by most physicists, namely, that the sun with all the planets will in time grow too cold for life, unless indeed some great body dashes into the sun and thus gives it fresh life. Believing as I do that man in the distant future will be a far more perfect creature than he now is, it is an intolerable thought that he and all other sentient beings are doomed to complete annihilation after such long-continued slow progress."
>
> From Charles Darwin's autobiography, 1887

The purpose of this chapter is to introduce different key themes concerning the developments in science and literature in Victorian England around the middle of the nineteenth century, c. 1840–1880. Though the main focus of this dissertation will concern only a few decades of the nineteenth century, this chapter will take up a broader perspective embracing the nineteenth century as a whole, in order to give a thorough characteristic of the relationship between science and literature in the period. Some of the aspects that will be dealt with in this chapter will be used later in the case studies as points of reference and as a starting point for reflections and further discussions in later chapters.

The chapter will consist of four main sections: Firstly, a brief account of how science was viewed in the period including some aspects of the development within the historiography of science. Secondly, I will take a look at two of the most important scientific theories of the time, namely evolutionary theory and thermodynamics, and how scientists were able to construct a continuous narrative around these particular scientific theories. Thirdly, two aspects concerning the public view of science will be dealt with. In both cases, the role of science in the educational system and the rise of popular science emerge as themes for discussion. In the case of popular science as well as in the debate on science as a part of the educational system, literature played a central role both as an assistant to science and as an opponent. Lastly, I will concentrate on a more detailed examination of how literature and science mutually influenced each other. Overall this chapter will describe different views of science in the period both from the perspective of the scientists and the public. This exploration will therefore address both the broad questions as well as the detailed ones, leading to a characteristic of the 'archetypal' scientific text and science's interaction with literature.

As the main focus of this dissertation is the influence of literature upon scientific texts, I will primarily address the scientific writings throughout this chapter. I will briefly define the types of sciences and scientific writings that will be of interest to this dissertation, herein also the forms of literary perspectives that will be relevant for my study of the scientific texts. A more detailed clarification of the theoretical foundation for this dissertation (in connection with literary criticism and the history of science) will be dealt with in Chapters Two and Three, respectively.

For many sections of this chapter I rely primarily on books and articles written on the relations between literature and science. In particular, I use LAURA OTIS' introductions from the anthology *Literature and Science in the Nineteenth Century* (2002), which give very precise and in-depth views of the many different interrelations between literature and science in the period. Similar accounts of the relationship between science and literature have been made, for instance by J. A. V. CHAPPLE, L. J. JORDANOVA, GEORGE LEVINE, and STUART PETERFREUND,[1] to which I will also return in later chapters.

1.1 Science and the History of Science in the Nineteenth Century

The nineteenth century was a century characterised by many contrasts both within science and in society in general: Science challenged religious views. The standards of living were improving although there was still a great deal of social inequality. And there was a feeling of optimism but at the same time also a fear of the apocalypse. In view of these many disparities in the Victorian Period, the progresses of the natural sciences were quite remarkable. In the early 1830s the scientist and philosopher WILLIAM WHEWELL (1794–1866) coined the term 'scientist' as a substitute for the term 'natural philosopher'. This new word quickly came to signify the student of the natural and physical world.[2] In addition, the terms 'science' and 'scientist' implied the rise of new scientific practises that relied on empirical methods of experimentation.

As the century moved forward, there was a growing awareness of science in the public and at the same time science became increasingly professionalized. These circumstances also made it more visible that the Bible no longer could uphold its sole authoritative voice when it came to for instance the age of the world and development of the human species. As the century went on, scientists continued to challenge the predominant religious views of nature as well as past scientific theories and methodologies. However, although there

[1] Chapple 1986; Jordanova 1886; Levine 1987; Peterfreund 1990.

[2] Shuttleworth and Cantor 2004, p. 2.

was an increasing scepticism about religion, the majority of people, including scientists, did not question the existence of God; rather scientists questioned the role of certain religious dogmas and interpretations of nature, and saw science as just another way of creating order in the universe.[3]

Not only did Whewell coin the word 'scientist', he was also one of the first people to write an account of the history of science. The fact that the history of science as a discipline began to expand in the period also helped scientists to become increasingly aware of their role in society and their identity as scientists (as opposed to for instance natural philosophers). The few accounts that had been written prior to the nineteenth century on the history of science had presented science solely as a progressive undertaking;[4] that is, science can only move forward to a higher (and thereby superior) level. Even though progression dominated the scientific discourse in the century in general, a scientist like Whewell believed that scientific progression was in itself not sufficient. According to Whewell, it was also necessary to find a universal scientific method which could help nourish science. Whewell's solution was the inductive method which he thought to be the only true scientific method.[5]

Whewell's view on science is remarkable not only because he presents a new vision of science, but also because his writings assimilate the inductive method he introduces. On Whewell's writings Jan Golinski argues that: "The narration of progress was designed to display the working through of the inductive method and to recommend its continuing use of science".[6] Thus, the rhetoric and language of Whewell's writings were in some ways concordant with his method. This was a very characteristic aspect of scientific texts in general in the Victorian period in particular (see below). Hence, Whewell's account of the history of science is characterised by having a significant narrative structure. Science, according to Whewell, is a story that should be told, and with the aid of a specific method, the story would be universal and could be viewed as a continuous whole. The view of science that Whewell represented was characteristic of the latter part of the nineteenth century, as will be illustrated in the following chapters.[7]

Since the Scientific Revolution in the seventeenth century, science had moved towards a more empirical and experimental way of studying nature, which in the latter half of the nineteenth century became the prevailing method of the natural sciences. Three main developments in nineteenth-century natural sciences are particularly relevant when dealing with the scientific writings of the period. Firstly, the period witnessed some extraordinary scientific breakthroughs and theories, for instance, evolutionary theory, elec-

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[3]Bowler and Morus 2005, pp. 346–350.

[4]Viewing science only as a progressive undertaking lived on for a considerable amount of time and still can be found in especially internalist history of science (Golinski 1998, pp. 4–6).

[5]Later historians of science rejected both the notion of science as only progressing to a higher level and the notion that science was dependent on a particular scientific method. In Chapter Two I will return to the discussion of the view of science in the nineteenth century.

[6]Golinski 1998, p. 4.

[7]Brooke and Cantor 2000, pp. 141–143; Golinski 1998, pp. 2–4.

tromagnetic theories, geological theories of the age of the earth and many more. Secondly, in the period the natural sciences split into many different disciplines (such as biology, meteorology, etc.) which themselves developed new independent scientific methods, vocabularies and had their own publications and societies. This growth of scientific disciplines also assisted science in becoming more professional, and as a result science played a larger role in the educational system in general: Science went from being the leisurely pastime of gentlemen scholars to become scientific disciplines exercised by professionally educated scientists.[8]

Lastly, the nineteenth century was the century when science truly became 'popular'. Already from the eighteenth century, the rising middle class showed a growing interest in science. Science was no longer only something of interest to the aristocracy, but began to have an impact on the lives of ordinary people. The term 'popular science' originated in the early nineteenth century and was linked to the professionalization of science. Jonathan R. Topham presents his version of the relation between popular science and the professionalization of science as follows: "[T]he origination of a new specialized and disciplinary notion of 'science' in these years — what has been described as the 'inventions of science' — was closely associated with the development of new 'popular' audiences both for science and, more generally, for printed matter".[9] Accordingly, popular science became an integrated part of the increasingly professionalized nineteenth-century scientific disciplines.

At the beginning of the nineteenth century, the Romantic Movement reached its peak. This period was in many ways remarkable in light of how literature and other forms of aesthetic practices functioned as an accepted part of the natural sciences. In many ways science and the arts were intertwined. Furthermore, there was a general belief at the time that science combined with for instance literature and art could get closer to fundamental truths in the world than science single-handedly could, because the concrete scientific facts combined with certain more non-scientific insights would give a better chance of finding the secrets of nature. This respect for and interest in the arts continued to characterise aspects of the natural sciences throughout the nineteenth century. Even as science became more professional and the positivistic movements became predominant in science, science and the arts continued to be great influences on each other — the boundaries between the two remained very much flexible. Thus, throughout the nineteenth century there was a strong relation between science and literature, but as we shall see later, the growing professionalization of science also came to be the basis of quite the opposite development, namely the beginning of a separation of the two disciplines.[10]

With positivism, scientists searched for law-like patterns in nature, and religion and metaphysics were no longer as fundamental parts of science as before. This increasing professionalization of science fit well with the positivistic doctrine which stated that the

[8] Otis 2002, pp. xvii–xxvi.
[9] Topham 2007, p. 136.
[10] Golinski 1999, pp. 2–10.

practices of science should be specialised. Science now searched for general laws in the natural world, as Whewell also argued.[11] In addition, the positivistic movements were in keeping with the specialisations of the different scientific disciplines: Structures in nature could be simplified so that for instance heat in the nineteenth-century version focused on the movements of molecules. Moreover, the specialised scientific disciplines also demanded a specific language-use (for instance formulas or specific scientific terms), whereas the general laws of science could be spoken of in a language that also would translate into other discourses at the time, for instance a literary one. This new consciousness of language meant that the biblical references and language that had also been employed previously had to be reconsidered and in some cases renewed.[12]

Science in the nineteenth century flourished in more than one way. Not only was science expanding its fields of interest but also new disciplines were founded and the practitioners of science were now educated professionals. In addition, science was becoming a strong authoritative voice which helped scientists to write and communicate new types of narratives and stories of science. But perhaps most important of all, nineteenth-century science delivered some extraordinary scientific theories that also had significance outside the scientific community.

1.2 The Great Scientific Narratives of the Nineteenth Century

In the Romantic period when the natural philosophy was the predominant movement, the main focus of the natural philosophers was to seek the overall coherences in the universe, or to put it in other words, to find a world soul.[13] In the latter half of the nineteenth century, the main narratives focussed on history and development: How nature has and will evolve and the processes taking place in nature. This underlying narrative structure naturally translated into the scientific writings of the time. Many scientific theories of the nineteenth century contributed to this understanding of writing the large-scale history of nature. Thereby certain scientific theories, like evolutionary theory and geological theories concerning the age of the world, were written in a narrative form that emphasised the large-scale developments. This also meant that scientific narratives no longer relied exclusively on either the storylines of natural philosophy or the Bible, instead new forms of narratives had been established and they were designed to fit scientific texts and more importantly science communication.

In the 1850s, two major scientific theories had a huge impact on both the scientific community and society in general. In 1851, the scientist William Thomson (1824–1907), the later Lord Kelvin, published the first of a series of articles on thermodynamics (heat

[11] Jordanova 1886, pp. 30–31.
[12] Bowler and Morus 2005, pp. 347–349.
[13] Bowler and Morus 2005, p. 84.

theory) in which he proposed, among other things, the second law of thermodynamics, the so-called theory of heat death. To put it simply, the first law of thermodynamics states that there can never be a loss of energy in a closed system; one form of energy will always be transformed into another form of energy. The second law of thermodynamics, however, defines that in any given closed system it is impossible to carry out a process in which energy is transferred from a colder body to a warmer one, which basically means that it is impossible to reverse energy — a vase that shatters will never 'un-shatter' again (at least not within the known universe). The universe itself is as such a closed and irreversible system with a certain amount of energy, where warmer bodies will transfer heat to a colder, which in the end means that every form of energy will transform into the same state. In other words, in the end everything will consequently have the same temperature and no form of energy can be transferred and everything will be still — the so-called heat death.[14]

Thermodynamics was not a new theory, but Thomson and other scientists like Hermann von Helmholtz (1821–1894) and James P. Joule (1818–1889) were reformulating the theory of heat which resulted in Thomson formulating the two first laws of thermodynamics. One of the most influential scientists in the field of thermodynamics was, however, James Clerk Maxwell, who amongst other things attempted to defy the second law of thermodynamics by introducing a thought experiment presenting a Demon (or a being as Maxwell himself called it), who had the ability to move energy from colder bodies to warmer without effecting the molecules. The being was able to reverse the second law of thermodynamics.[15] Thermodynamics had a tremendous impact on science and society in general, because it professed that the universe at some specific point in time was going to die because everything would be at a stand-still. The most important narrative that the scientists of thermodynamics conveyed to the public was therefore also the story of how the world and entire universe would eventually end.[16]

The other grand scientific narrative of the nineteenth century was the theory of evolution. In 1859 Charles Darwin published his *On the Origin of Species*,[17] a groundbreaking book both by nineteenth-century and today's standards. Darwin's book became a bestseller but also created a fair amount of controversy. The success of *Origin* was both on account of its content but also because the book was written in a non-scientific language without mathematical formulas or scientific jargon. Furthermore, Darwin conveyed his theories by telling a 'closed' story of the evolution of the species from past to present and gave further indication of what would come in the future. By the end of the nineteenth century, the scientific community and the public had generally accepted evolutionary theory. In addition, evolutionary theory was on the curriculum in both schools

[14] Bowler and Morus 2005, pp. 92–93, 124.

[15] Maxwell and his Demon will be dealt with in detail in Chapter Four.

[16] The thermodynamic narrative of how and when the world would end had an obvious counterpart in the Bible, and liberal theologians found this cosmology as well as Darwin's evolutionary theory to be a source of inspiration (Bowler and Morus 2005, pp. 362–364).

[17] Henceforth abbreviated *Origin*.

and universities by the end of the century.[18] Like the case of thermodynamics, DARWIN was not the sole originator of his theory of evolution. Many other scientists had dealt with the way in which species evolved. DARWIN, among other things, sought inspiration in CHARLES LYELL's books on the principles of geology, in which he claimed that the earth was far older than stated in the Bible. Furthermore the themes of time and development (or progress and evolution) were indeed, as mentioned, omnipresent themes in most scientific disciplines.

The core of DARWIN's book is the claim that humans are like any other animal and that all species have evolved since the dawn of time. Fundamentally, the claim that humans are no different from any other animal challenges our self-understanding as humans. However, DARWIN did not speak of how the different species originated or were created but only of how they have evolved, but despite this he was criticised for both claims, especially by people with strong religious views.[19] Despite the fact that the theory of evolution quickly became an integrated part of the scientific world and in popular culture, the theory itself is not based on empirical facts,[20] which DARWIN himself states in the beginning of *Origin*, as one might expect of a book that set the standards for a new view of the human race.[21]

Even though the nineteenth century saw many new and groundbreaking theories, thermodynamics and evolutionary theory sum up the two main themes of nineteenth-century science, culture, and literature, namely on the one hand energy and force[22] and on the other hand origin and development. Furthermore, both theories showed the irreversibility in the world: No process could be reversed, neither evolution nor the transformation of energy. In addition, the terms of evolution and origin are both at the same time concrete and abstract notions: Both themes involve a reflection of time and how things originate, develop and die out, and in this respect they do not differ from any other existential contemplation in other periods of time. But in the nineteenth century, science gave a version of these themes, not excluding religion entirely,[23] but pointing out the fact that there are fundamental existential conditions in the universe that can be scientifically explained.

Although evolutionary theory and thermodynamics had certain similarities in terms of their views of the world, there were also differences. DARWIN's theory of evolution basically told the story that all species would continue to evolve to still higher levels

[18]Cahan 2003, pp. 313–317.

[19]One of the most heated confrontations was between DARWIN's supporter HUXLEY and Bishop WILBERFORCE (see Bowler and Morus 2005, pp. 354–360).

[20]Which also was the case of other theories of the period, as already stated many elements of for instance thermodynamics were not based on empirical facts.

[21]See Chapter Three, p. 58.

[22]Energy in this context is a very broad concept and thus light, electricity and magnetism were understood as energy (Bowler and Morus 2005, p. 93).

[23]As mentioned above, the majority of scientists in the period were not atheists: THOMSON for instance believed that God was responsible for the precise amount of energy in the universe. Likewise, DARWIN did not question that God had created the universe, he theorised only on how life evolved after the creation.

of development, whereas the story of thermodynamics ended everything with the heat death. Both of these stories translated into a cultural context as myths rather than exact scientific theories. A great number of literary authors incorporated these scientific stories into their works of fiction. In particular, one author managed to include aspects of both the evolutionary and thermodynamic narratives in one single novel George Eliot's *Middlemarch*, written in 1871–2, to which I will return below.

1.3 Growing Popular

The Great Exhibition in 1851 was an important event in showcasing Victorian science. The exhibition was held in the Crystal Palace in London and displayed the progress in science, industry, technology and the arts. The Great Exhibition was immensely popular and was visited by over six million people, almost a third of the population of Great Britain at that time. Besides being a symbol of the Victorian Age and the capabilities of Victorian science, the Great Exhibition was a demonstration of the fact that science had become an interest of the common man. People were both fascinated by and somewhat reluctant to accept what science and technology were able to do, but there was a general feeling that in due time, science would be able to solve all the problems of mankind.[24]

Figure 1.1: Interior from the Crystal Palace, London, which housed the Great Exhibition in 1851. Alongside the newest in science and technology were sculptures and other artworks displaying the cultural and technological progress (or evolution) of the nation. (Source: Wikimedia).

There were, however, other ways in which the general public could come into contact with science. In various scientific societies, many lectures were organised which targeted

[24] Sanders 2000, pp. 400–401.

a non-scientific audience. These lectures were often attended by a great number of people, including also many literary authors. The individual scientific disciplines were also flourishing in the written media with groundbreaking publications like those of Darwin. Even more significant was the huge increase in the number of publications of periodicals and journals witnessed in the century.[25] The Victorian periodicals were both of general and special interest. The periodicals of general interest functioned as a platform for communicating scientific ideas to a broader audience. Many scientists wrote for periodicals that published popular science articles, not only because they wanted to communicate their scientific findings and theories to a broader audience, but also for financial reasons. As the century progressed and the interest for popular science rose, more money was to be made in both writing popular articles or books and giving public lectures.[26]

Many of the general periodicals in the Victorian period had scientific articles appearing side by side with articles on literature, politics, religion, psychology and the fine arts, and in some cases even original poems and short stories. Many scientists as well as literary authors interacted through such periodicals: For example Eliot and her husband George Henry Lewes (1817-1878) helped edit the general periodical *Westminster Review* (1824–1914) that printed both specialised scientific articles and literary articles.[27] Many of the general periodicals, to which numerous cultural and scientific writers contributed, did not survive many years. However, many of the publications lived on to become highly specialised, addressing only professional scientists and not the general reader. The rise in the number of scientific publications in the Victorian Period did not imply that science was written in a specific language that only specialised scientists could understand. As Otis writes "Science was not perceived as being written in a 'foreign language' [...] As a growing system of knowledge expressed in familiar words, science was in effect a variety of language".[28] All in all, the many publications, lectures, exhibitions and other circumstances helped popularise science to a broader nineteenth-century audience.

Seen in a historiographical perspective, the interest in popular science within the history of science has grown over the last couple of decades. Various communication models have been employed to interpret the relations between the scientist and his audience.[29] For the purpose of this dissertation, however, only the relationship between popular science and professional science will be of interest. In the mid-eighteenth century the middle class gained more and more power, and public institutions such as museums developed and became increasingly popular with the new audience. In the same period, scientific explorations and their popularity also increased. According to some historians of science,

[25] There were approximately 125,000 different publications through the century (Shuttleworth and Cantor 2004, p. 1).

[26] Otis 2002, p. xx.

[27] Shuttleworth and Cantor 2004, p. 5; Chapple 1986, pp. 4–10.

[28] Otis 2002, p. xvii.

[29] In connection to the scientist-audience relationship, which will be treated in Chapter Three, I will not look at specific communication models but instead look at how the scientist in his text shows that he is aware of his audience and who they are.

popular science has to do with consumer choice — science like many other things became a commodity (and even with a high entertainment value) to the middle class from the end of the eighteenth century.

Science understood as a commodity can be seen as a strong contrast to the notion of science as an unbiased and truth-finding venture, which it is often viewed as.[30] It was not only high-profiled scientists like DARWIN who contributed to the popularisation of science: Scientists in general were conscious about science becoming professional and popular at the same time and the fact that science was becoming a professional venture that demanded certain equipments and locations (for instance a laboratory). At the same time, science also explored its entertainment value, for instance, by showing the general public that science could also produce amazing scientific instruments, optical illusions, electricity and many other tangible wonders. Thereby, scientists were very conscious of the dividing line between science as a profession and science as entertainment and took part in emphasising both sides of their trade.[31] Furthermore, science's role in the educational system became an important issue in the period. Certain scientific theories, like the theory of evolution, began to attract attention and support in academic circles and therefore the discussions in the educational system began to flourish regarding science's role in the core curricula of schools and universities.

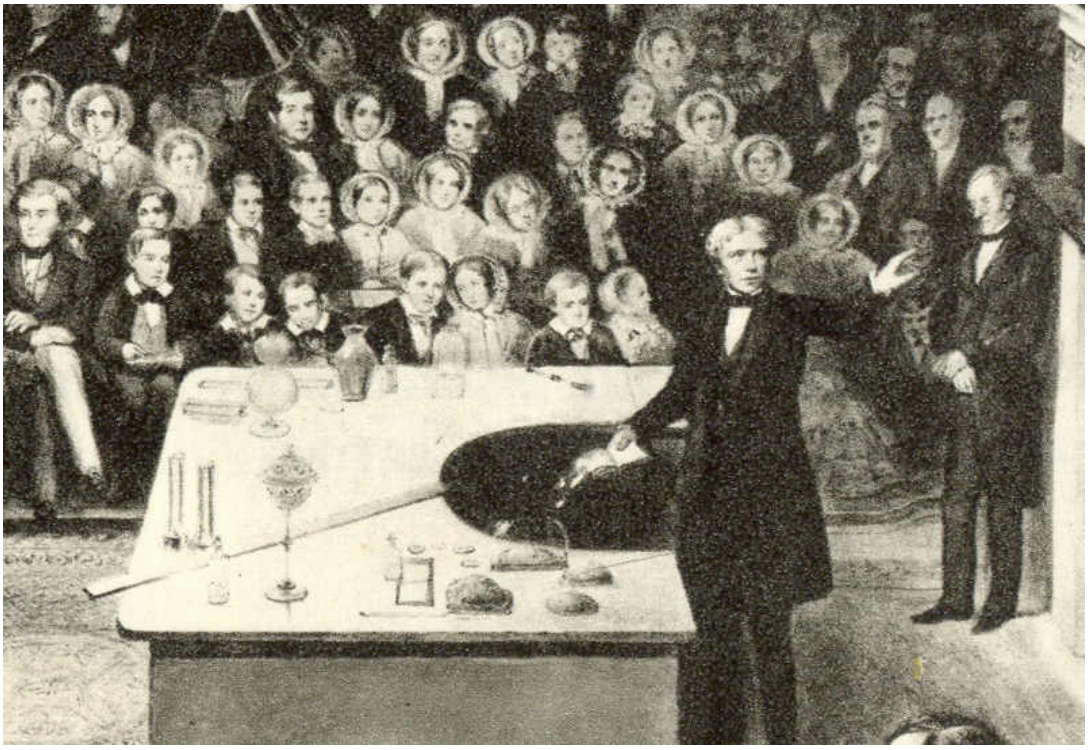

Figure 1.2: Scene from a public scientific lecture. In this lithograph, FARADAY *entertains the audience with a lecture on chemistry and physics at his Christmas Lecture in 1856. Note the number of young listeners in the audience. (Source: Wikimedia).*

[30]van Wyhe 2007, pp. 77–79.
[31]Lightman 2007, p. 126; Morus 2007, p. 350.

1.4 Education in a Scientific Discussion

The most noticeable debate on science education was between the literary author and critic Matthew Arnold (1822–1888) and the scientist T. H. Huxley (1825–1895). At the heart of the debate on education was the question of the nature of 'literature'. The word literature in the nineteenth century came to be defined as fiction.[32] But Arnold believed that all forms of text should be seen as literature, which in the end meant that fiction should have the same emphasis in the educational system as, for instance, the natural sciences, because every variety of text has an influence on human life and culture in general.

Contrary to Arnold, Huxley saw literature as only including fictional works and stated that: "Technological advances and transformative new theories had made science as essential to culture as Horace's poetry had once seemed to be".[33] At the opening of a science college for working- and middle-class students in 1880, Huxley stated that an exclusively scientific education would be just as beneficial for society and culture in general as an exclusively literary education. This was a provocative statement made by Huxley and incensed Arnold, who believed that Huxley's definition of literature was too constricted.[34] The fact remains that in the beginning of the nineteenth century, the educational system was based on a classical literary education. Scientists were educated in classical literature and therefore it was natural for them to use this knowledge in their scientific works. By the end of the century it was possible to receive an education with emphasis on science exclusively, which naturally had an impact on the ways in which science was communicated. This development continued into a highly scientific and technical language-use that has become synonymous with the scientific writings of the twentieth and twenty-first centuries.[35]

The debate on education between Arnold and Huxley is an indication of the fact that, on the one hand, literature and science were not as intertwined as they previously had been. On the other hand, the rise of popular science and science communication meant that scientists utilised literature, literary media and literary devices to communicate their science to a larger audience. In the late nineteenth century there was not only a feeling that science and literature were integrated part of each other pointing back to the Romantic period (and prior), but also a feeling that science was separating itself from literature and moving towards more specialised discourses that have been elaborated on from the last decades of the nineteenth century. However, this specialised discourse was far from most scientific writings at that time, which in many respects were literary.

[32] It was not until the nineteenth century that literature was divided into the fiction and non-fiction. Before the nineteenth century the word literature had included every form of text (Otis 2002, p. xvii).

[33] Otis 2002, p. xviii.

[34] Otis 2002, pp. xvii–xviii.

[35] Otis 2002, p. xix.

1.5 Literature in Science — Imagination and Narrative

One of the ways in which scientists in the Victorian period still managed to incorporate literature into their writings was through imagination. John Tyndall even wrote an essay "On the Scientific Use of the Imagination", 1874, in which he proclaimed that there can be no doubt that imagination is present in every written text, and especially in scientific texts, in order that the scientist might convey his thoughts. Furthermore, Tyndall argued that science has a great connection with literature.[36] Imagination in the Victorian Period meant that the scientists could be prophetic and visionary, for instance by declaring that the sun would burn out at a particular point in the future, like Thomson did in his article "On the Age of the Sun's Heat".

Scientists relied on imagination in the same ways that literary authors did, because science to some extent demanded literary language and imagery to present new and strange ideas. Scientists like Darwin and Michael Faraday (1791–1867) often directly asked their readers to 'imagine' something that was highly speculative. Otis writes: "[T]he necessary differences between literary and scientific writing led many nineteenth-century scientists to use fiction as a freer mode in which to explore provocative scientific ideas".[37] Otis writes further that scientists and literary authors employed the same strategies, like imagination, but that scientists tried to maintain a distance between themselves and "those whose imaginations were supposedly unrestricted by reason".[38] Whenever scientists (or authors) encountered something they did not understand or something they had difficulties explaining, they would use metaphors for instance when readers had to imagine how human evolution had taken place over thousands of years.[39] Scientists observed, described and to some extent deciphered nature and the texts that they produced needed to be subjected to a form of literary analysis by the reader.[40]

The fact that scientific texts were in some ways literary has to do with both the fact that scientists often quoted well-known poets in their texts and the individual styles of the scientists. Lyell, for instance, quoted poets and authors like John Milton (1608–1674) in his *Principles of Geology*.[41] Lyell used his literary quotations in order to indicate that he was well-educated and had knowledge of classical literary works, and that he was conscious about cultural history and cultural heritage. These quotations also helped to emphasise the fact that science was not only for the elite, but also something that could be read and understood by educated readers in general.[42] Later in the century, scientists with a scientific education did not use literature as references to their knowledge of classical literary works as Lyell did. Instead, literary elements in scientific texts helped

[36] Otis 2002, pp. 68–70.
[37] Otis 2002, p. xxiii.
[38] Otis 2002, p. xxiii.
[39] Otis 2002, pp. xxi–xxii.
[40] Beer 2000, p. 84; Otis 2002, p. 131.
[41] Lyell 2005.
[42] Otis 2002, p. xix.

the scientists to persuade their audience of their theories, because the theories became more accessible to the readers when they included literary points of reference. Thus, the scientists in general adopted a literary language-use and imagery in order that their audiences might better understand the science. Of course, the more stringent form that has characterised scientific theories since the Scientific Revolution is still visible in the scientific texts. Furthermore, scientific texts were still influenced by systems and rigidity in terms of form (for instance certain systems or methods of description within a particular scientific discipline), whereas the content in some ways could be literary and amorphous without the scientists having to abandon their scientific ideals.

1.6 Science in Literature

It was not only literature which had an impact on science in terms of style, and in particular content. It was also possible to see the influence of science in many literary works. In this section I will briefly consider the further ways in which science and scientific themes and theories played a role in many fictional works and in the lives of literary authors. Though this dissertation deals with literature in science and not science's influence on literature, it is important to get a many-sided understanding of the complex relationship between science and literature in the period.

Already from the beginning of the nineteenth century, science and scientists played a central role in different literary works. In the beginning of the century the Romantic period delivered one of the most noticeable and classic novels about science, namely Mary Shelley's (1797–1851) portrayal of Victor Frankenstein in *Frankenstein — or the Modern Prometheus* (1818). This archetypal horrific tale about the brilliant scientist who attempts to play God is also a tale of two contradictory views of science: Victor Frankenstein rejects the new scientific method of empiricism and classification and instead gets his inspiration from alchemy and other questionable forms of science. In the same period, however, there were also positive encounters between literature and science: William Wordsworth (1770–1850), for instance, wrote on geology in some of his poems, praising the idea that geology and science together could uncover the laws and systems in nature.[43] Literature was slowly accepting the scientific explanations of nature and thereby also recognising that religion no longer had exclusive rights to the truth. Otis writes:

> Literary writers, who for centuries had told their stories in the cultural language of biblical tales, were able to challenge accepted views of human nature by interweaving traditional stories with new narratives made available by science [. . .] The innovative use of well-known tales was as essential to literature as it was to science.[44]

[43] Chapple 1986, pp. 160–161.
[44] Otis 2002, p. xx.

Science was increasingly becoming an integrated part of literature, and literary authors became inspired by the empirical scientific methods. These inspirations came across in the naturalistic and realistic novels, which were often concerned with facts, observation and experimentation.[45] An example of this is ELIOT's narrator in *Middlemarch* who observes her characters and their environment.

Middlemarch — A Novel of Science

Middlemarch stands out as a primary example of how literature was inspired by positivism and scientific methods in general. In many ways, ELIOT's novel is a typical Victorian character novel, where the story is set in a specific geographical space at a specific point in time, and has numerous characters that are linked to each other in different ways. The main reason why ELIOT's novel has been seen in a scientific perspective has to do with ELIOT's own interest in and writings on science. In many ways ELIOT epitomised the Victorian intelligentsia; she translated modern theological works,[46] had an interest in politics and sociology and was very interested in AUGUSTE COMTE (1798–1857) and JOHN STUART MILL's (1806–1873) positivistic theories. All of this influenced her fiction, most noticeably *Middlemarch*.[47]

In the small town of Middlemarch the inhabitants and the society within which they act evolve slowly and gradually, even though the novel can only show a fragment of human evolution since the story is limited to a short period of time. But ELIOT also sees the town of Middlemarch as a living organism in which people function as individual cells: This is connected to the declaration of intent with which ELIOT opens her book. SALLY SHUTTLEWORTH writes with this declaration in mind that: "*Middlemarch* is a work of experimental science: an experimentation of the 'history of man' under the 'varying experiments of Time'".[48] The narrator is therefore not simply an old fashioned type of (natural) historian that merely passively observes and describes the order of the world (or nature). Rather, the narrator uses a dynamic methodology of experimental biology and looks at her character from this perspective.

Still, both the experimental scientist and the natural historian are represented in the *Middlemarch*'s gallery of characters: One of the main characters in the novel is the doctor Tertius Lydgate, who, like the narrator, represents the experimental scientist. Lydgate becomes the pragmatic expression of the narrator's experimentations, because he believes in the new scientific methods (which he wants to introduce to the local hospital), and sets out to find out the cause of a particular type of fever that he wants to cure. On the other

45 Otis 2002, p. xxiii.

46 In 1846, ELIOT translated STRAUSS' work *Das Leben Jesu* from German. In STRAUSS' work he argued that Jesus was a historical figure and played down the miraculous circumstances of Jesus' life (McSweeney 1992, pp. 19–20).

47 Beer 2000, p. 42; Sanders 2000, pp. 441–442.

48 Shuttleworth 1992, p. 107.

hand, Lydgate's good friend the reverend Farebrother (who is also an amateur botanist) represents the natural historian and is the observer of nature and the order of nature. Both characters — Lydgate and Farebrother — are valued for their different methods by the narrator, although Lydgate's methods by far are more modern and progressive.[49]

Middlemarch can also be seen as setting a scene for ELIOT's explorations of different aspects of thermodynamic theories. In her article "Physics in 'Middlemarch': Gas Molecules and Etheral Atoms" SELMA B. BRODY describes how ELIOT incorporates thermodynamic theory into her novel, from ELIOT's use of words like force, energy and heat, referring to some of the characters and their actions, to how she builds up Middlemarch around the theory of kinetic energy. The inhabitants of Middlemarch are like molecules that randomly encounter and have an influence on each other.[50] According to BRODY, Lydgate is not a modern biologist at all, but a modern physicist. In chapter sixteen of *Middlemarch* Lydgate tells of the experiments he carried out in Paris before he came to Middlemarch, and how he envisioned future scientific ventures: "[T]he inward light which is the last refinement of Energy, capable of bathing even the ethereal atoms in its ideally illuminated space".[51] As BRODY declares: "This is a physicist's reverie, not a physician's".[52]

At the heart of the novel lie thus not only references to contemporary scientific theories and disciplines such as evolutionary theory, biology, thermodynamic and medicine, but also a fundamental acceptance and use of the new scientific methodology. In the new kind of science and ways of writing natural history, "[t]here can be no one-to-one correspondence between sign and signified, since meaning, like organic life, is a product of a total system",[53] as SHUTTLEWORTH argues. This argument can be seen in relation to ELIOT's novel, because her narrator and many of her characters (like Lydgate and the failed scholar Casaubon) attempt to determine and understand what is beneath the chaotic surface of the world, like the contemporary scientists did. SHUTTLEWORTH's view on the new kind of scientific writings she transfers to *Middlemarch* and in summing up ELIOT's novel SHUTTLEWORTH notes:

> Acting as a creative scientist, George Eliot offers, through the controlling experimental conception of a labyrinth, many levels of analysis of Middlemarch life. From the materialist analysis of property transmission she moves, through levels of ascending complexity, to consider questions of psychological and social structure, offering, at the highest level, an interrogation of the nature of historical understanding and mythic creation.[54]

With *Middlemarch* ELIOT managed to create a scientific novel that paid tribute to the new scientific methodology presented in an essentially stereotypical Victorian character novel. Furthermore, the novel describes a number of conflicts central to Victorian society

[49] Eliot 1965, pp. 116–117; Postlethwaite 2001, pp. 99–100; Sanders 2000, pp. 107–109.
[50] Brody 1987, p. 48.
[51] Quoted from Brody 1987, p. 42.
[52] Brody 1987, p. 42.
[53] Shuttleworth 1992, p. 108.
[54] Shuttleworth 1992, p. 126.

including the old scientific methods as opposed to the new ones, the conflict between science and religion, and last but not least the contradiction between professional and popular science and the question of how to communicate science to the public. The latter is most visible in Lydgate's battle to have his new ideas about medicine accepted by the people and politicians in the town, which also to some extent reflects the state of science communication in Victorian Britain at that point in time.

Beyond Eliot

Victorian authors of fiction wrote on many of the conflicts and contradictions of the period, which sometimes also included the natural sciences. An example is how different scientific theories on how the universe and nature work were in opposition. Other topics of interest were progress of and within society with greater social mobility and prosperity versus a fundamental feeling of pessimism about the future. But also conflicting political ideologies and the discrepancy between religious dogma and science were popular subjects. These subjects, directly or indirectly, served as the background for many of the novels and other literary works that were produced in the latter half of the nineteenth century.[55]

Most literary authors at some point in their works dealt with science or scientific themes: Charles Dickens (1812–1870) considered the question of origin in *Oliver Twist,* 1838; Thomas Hardy (1840–1928) challenged traditional astronomy in his novel *Two on a Tower*, 1882; H. G. Wells (1866–1946) explored the new understanding of time in *The Time Machine* from 1895 based on thermodynamic theories;[56] and Alfred Lord Tennyson (1809–1892) wrote on geological and paleontological matters in his *In Memoriam* 1850. However, it was not only a question of literary authors taking up scientific themes; scientists and literary authors shared discourses, ideas and metaphors. Likewise, both science and literature were an integrated part of society and culture, and both spheres used each other's ideas and forms of language.[57] In connection to the general themes shifting from a scientific context to a literary one, Chapple writes:

> The literature of the time shows minutely detailed responses to particular scientific discoveries [...] but more often it is great conceptual movements that shift the ways in which we apprehend the very nature of reality which are of prime importance; hence the fascination with origins, growth and transformation; the changing awareness of our relation to animals and plants; the new stress placed upon struggle for existence, progress and extinction; the growing determination to alter circumstances, especially human ones, by discovering how to predict and then change them; and throughout the century the constant desire to find a basic unity of forces and dynamic laws that reconcile or transcend opposites.[58]

[55]Chapple 1986, pp. 3–5.
[56]Wells 1971.
[57]Smith 2004, p. 94.
[58]Chapple 1986, p. 4.

Thus, scientific themes like progress and determinism influenced some of the central structures that were present in a number of novels in the period.

1.7 A Century of Contradictions and Progress

There can be no doubt that the second half of the nineteenth century was a very progressive time, but also a time of contradictions. On the one hand, science produced new and groundbreaking theories, found its way into the educational system and established a tradition for narratives and popular communication. On the other hand, science created big controversies especially when it came to clashes with certain religious views. From a literary perspective, the period saw great naturalistic and realistic novels; some of them revolved around the subject of science or used scientific theories as underlying themes. Throughout the century, science continued the search for universal truths and with the professionalization of science, positivistic dogma and empirical methods, the interest in science grew steadily. The public believed in science and its capabilities.

Furthermore, in the Victorian period science established itself as communicating the objective truth about the world. This happened despite the fact that popular scientific writings often were more like fiction in style than the more professional scientific writings which were, and still are, kept in a strict technical language. The popular side of science and the communication of science often meant that people would be presented with entertainment, illusions and mind-boggling stories alongside concrete scientific knowledge and results. Thus, the notion of the 'reality' of the world and science's role therein was not as straightforward as it might appear.[59]

Overall, however, science was progressive, and together with literature the two disciplines managed to benefit from each other in different ways. The natural sciences used the literary style and language as part of their communication, and the naturalistic and realistic works of fiction gained from science's credibility. Sometimes it was hard to know whether a text was science or fiction. Some literary writers wrote their fiction in a scientific style and some scientists wrote in a predominant literary style. This tendency was not only a question of style, but also a part of a 'game' in the period, when some literary and scientific writers explored and exploited the fact that the genres intermixed and were difficult to distinguish from each other.[60] Thus, at the end of the nineteenth century there was no gap between science and literature, and both fields had a huge impact on society in general, in the educational system and as a way of communicating science to the general public. And perhaps most importantly, science and literature were becoming aware of the ways in which they could benefit from each other.

[59] Morus 2007, p. 364.
[60] Otis 2002, p. xxiv.

Defining Literature and Science

As a closing remark to this chapter I would like briefly to comment on how the connections between literature and science are described. Throughout this chapter, I have relied on several works written specifically on literature and science by writers working within the field of literature and science (which will be described in full in the following chapter). Reading through many of these works on literature and science a few things call for further investigation. The cornerstone in the basic story about the relationship between literature and science revolves around the concept of the 'two cultures'. The writers dealing with literature and science tend to view the relationship between literature and science, or the two cultures, in very general terms, thus for instance literature and science were closely intertwined until the last decades of the nineteenth century. However, it seems that the writers rarely discuss literary works that are critical of science (or scientific works that are critical towards literature, for that matter) written in periods when science and literature were supposedly close. An example of this is how the Romantic period is described as a period when science and literature were hard to distinguish, despite the fact that a poet like John Keats (1795–1821) was very critical of science. In his poem "Lamia" from 1819 Keats describes science as 'cold philosophy':

> And for the youth, quick, let us strip for him
> The thyrsus, that his watching eyes may swim
> Into forgetfulness; and, for the sage,
> Let spear-grass and the spiteful thistle wage
> War on his temples. Do not all charms fly
> At the mere touch of cold philosophy?[61]

Keats' poem is just one example of literature that is critical of science in periods when literature and science were close. I do not doubt that the writers within the field are aware of the critical works, but there is a tendency only to include works of science and fiction that show the positive relations between literature and science and to base analyses of the relationship between literature and science from this perspective. And in the periods when literature and science have been seen as separate discourses, the writers of the field of literature and science tend to focus on texts that reject this separation by employing elements from the other discipline. Thus, one should be aware of how the writers dealing with the relations between science and literature construct their literary historical arguments as well as their arguments of the history of science.

[61] Quoted in Abrams 1993, p. 811.

Chapter Two

The Field of Literature and Science

> "All meanings, we know, depend on the key of interpretation."
>
> George Eliot

Since the 1960s, the awareness of the significance of narration, storyline and language has increased in the writings of history in general and history of science in particular.[1] Theorists like Michel Foucault (1926–1984) and Thomas Kuhn (1922–1996) focused on language and how it works in different forms of writings, which prompted a general interest in the significances of language. This new interest in language and the theories that followed influenced many humanistic theories, but also the history and philosophy of science. In the last quarter of the twentieth century, scientists, literary scholars, philosophers and historians of science started to take an interest in bridging the gap between science and the humanities. The studies of the connections between art and literature and technology and science resulted in the development of new interdisciplinary approaches. This field of literature and science has expanded ever since and is increasingly becoming an accepted method for analysing certain aspects of the history of science, science communication and specific scientific writings. The field also has a number of academic societies, the most significant being the *Society for Literature, Science and Art* (established in 1985), publisher of the journal "Configurations" that deals with the interrelations between science and the arts. One of the main motivations behind the society was to "develop a grand unifying theory of literature and science"[2] — and although there have been attempts to create such a unifying theory, the construction is still very much in progress.

The aim of this chapter is to give an overall characterization of the field of literature and science as well as a reflection on the historiography of the history of science surrounding the field. This chapter will be dealing with four aspects of the field of literature and science: Firstly, I will give a brief account of the origin and development of the field from the 1960s and forward and herein explore the characteristics of the field including a brief look at the key contributors in the field. Secondly, I will take a closer look at the theories and methods of the field and how these theories and methods are applied in relation to the different sources in the field. Thirdly, I will look at a central

[1] Golinski 1998, p. 187.
[2] Gossin 2002, p. 94.

and basic conflict in the field between on one side the literary critics and on the other side the historians of science writing within the field. This conflict between the scientific and literary contributors not only stems from different approaches to science in texts, but also has to do with different views of science and language in general. The conflict will be taken up again in Chapter Three and additionally explored further in the last section of this chapter, in which I will take a closer look at the constructivist theories as means of analysing the relations between science and literature: Both the historians of science and the literary critics employ constructivist methods when analysing literature and science, however with very different emphases. The constructivist approach will also serve as a starting point for the construction of the analytical model in Chapter Three.

Over the recent decades both historians of science and literary critics have taken a new and wide-ranging interest in the various connections between science and literature. Subsequently, a substantial amount of articles and books have been written about the correlations between literature and science. Some of the earlier works in the field first and foremost dealt with the impact of scientific ideas on literature, an example is how an author like Thomas Pynchon in many of his novels and short stories incorporates thermodynamic theories.[3] Today, the field can basically be divided into two subcategories, namely how literature was and is influenced by science and how science and scientific ideas were and are influenced by literature and literary elements. Most of the works on literature and science deal with how science has influenced literature. Typically, a single novel or a particular author's body of works are analysed with an outlook on specific scientific ideas or theories. When writers previously have written on the impact of literature on science, it has often been centred on structural elements and the rhetoric and language of scientific writings. Rarely has anybody focused on individual works of fiction and their direct or indirect influence on scientists and scientific developments.

Contrary to this, the analyses of the impact of science on literature are almost always directed at particular scientific texts, theories and ideas and their role in a particular novel or poem. Literary critics have dominated this section of the field, investigating science's influence on literature. Consequently, many analyses testify to the increased focus on textual structures, language and the process of translating scientific discourses into fiction. Even though the field of literature and science is usually divided into the two abovementioned subcategories, most writers today seek to view literature and science as independent of each other. This is done, for instance, by considering literature and science as autonomous discourses and analysing them from either a literary perspective or the viewpoint of the historiography of science.[4]

I have chosen mainly to focus on the methods and theories of the historiography of science, with the emphasis on constructivism, which thus will function as the histori-

[3] Cartwright 2007, pp. 115–116.

[4] Although the main focus of this dissertation is on the nineteenth century, I have chosen in this chapter also to include works on other periods, since the works included serve as better and general examples which also can be transferred to a nineteenth-century context.

ographical background for this dissertation. The choice was made for two main reasons. Firstly, the constructivist approaches are the most applied ones in the analyses of literature and science (both in the case of science's influence on literature and vice versa). And secondly, the constructivist methods focus greatly on the textual level of the scientific writings, and often apply elements of textual analysis.

2.1 The Nature and Origin of the Field of Literature and Science

As mentioned, the field of literature and science is largely founded on the constructivist movements beginning in the 1960s. In the historiography of science the sociology of science was the prime result of the constructivist movements. John Cartwright, a biologist and historian of science, writes in an essay on the history of the field of literature and science that the methodological approaches of the field are partly Strong Social Constructivism[5], New Historicism[6] and partly thematic approaches (a concrete manifestation of the latter is for instance in the form of an anthology with a specific theme).[7] Social constructivism has no doubt dominated the field and furthermore is seen as a method, which has the ability to: "illuminate the generation of scientific knowledge" and even treats science as an: "epistemologically unprivileged discourse or narrative", as Cartwright argues.[8] This latter form of extreme social constructivism has mostly been put forward by literary critics and been attacked mostly by historians of science writing within the field. Since the 1980s there has been a growing interest in the new historicist approach at the expense of constructivism, where literature and science both are proven to be the products of a common culture, and thus ideological, social and cultural relations between and within literature and science are taken into consideration.[9]

As indicated above, there are many different ways to approach and characterise the field of literature and science and how writers within the field go about analysing literature and science in relation to each other. Here we may again turn to Cartwright, who in his essay "Science and Literature: towards a conceptual framework" from 2007, divides the field of literature and science into eight different categories:

1. Science as a source of images, metaphors or explanatory devices
2. Science derided, rejected and satirised

[5]Strong Social Constructivism claims that all knowledge and science can be interpreted and seen as social constructions (Bloor 1991, pp. 3–8).

[6]The literary approach formed in the early 1980s that approaches a text in relation to its historical and cultural context, that is the text is situated in particular social practices, institutions and discourses (Abrams 1999, pp. 182–183).

[7]In addition to Cartwright's classification, one could also mention the biographical approach as a significant way of dealing with literature and science, for instance by looking at which fictional works scientist read and which authors they associated with, etc.

[8]Cartwright 2007, p. 116.

[9]Cartwright 2007, pp. 115–117; Peterfreund 1990, p. 3.

3. Science as provoking cognitive dissonance requiring intellectual accommodation and negotiation
4. Science celebrated with the scientist as hero or science applauded as evidence of divine power
5. Didactic verses (poems of science)
6. The Romantic notion of science as cold and inhuman (e.g. Frankenstein)
7. Scientific irresponsibility (e.g. the Faust figure)
8. Literature and science claiming ontological primacy

The first seven categories can be seen as ways in which literature has discussed science through its history from c. the sixteenth century to the present day. However, it also shows methods of comparing and analysing different historical periods that can be employed when discussing the interrelations between science and literature.[10,11]

Cartwright's eighth and last category, that literature and science claim ontological primacy, differs from his other categories in the respect that it does not stem from analysing specific literary or scientific works. Rather, the category represents the general notion of the field of literature and science today, especially from the point of view of the literary critics:[12] Claiming ontological primacy for either literature or science can only be done when one has a particular outlook on the two disciplines.[13] In order to investigate how science has influenced literature, writers in the field of literature and science have come to the conclusion that science is a profound and integrated part of culture in general and is no longer only claiming to state the truth about nature. In turn, literature: "no longer merely describes the progress of the sciences";[14] literature can help communicate science in new ways. Therefore, many of the theorists of literature and science view science as a form of discourse alongside with the literary discourse. In this respect, science no longer has exclusive rights to the truth about the world, but can be broken down into linguistic units and analysed in the same respect as for instance Social Constructivism breaks down science into social structures.[15] Thus, by viewing science and literature as equal forms of discourses, it is possible for the scholars to put text against text and language against language: This approach to literature and science has mainly been taken up by literary critics, often post-modernists.[16,17] Although Cartwright's eight categories sum up many

[10]A similar classification of science and literature in a historical context can be found in Haynes' *From Faust to Strangelove — Representation of the Scientist in Western Literature* (Haynes 1994).

[11]Cartwright 2007, p. 117.

[12]Most notably the literary critics Beer and Levine.

[13]Cartwright 2007, pp. 133–135.

[14]Naumann 2005, p. 512.

[15]Richards 2003, p. 18; Levine 1987, pp. 4–6.

[16]Cartwright 2007, p. 133.

[17]A more recent approach to the study of literature and science is the so-called Literary Darwinism where literature is interpreted in light of evolutionary psychology. The Literary Darwinism Movement is going against the post-modern theories (like deconstructivism, feminism, etc.) of literary history and thereby also against the core of the field of literature and science (Cartwright 2007, pp. 135–136). Instead, Literary Darwinism takes a reductionist approach to literature, claiming that what is displayed in literature, in the end, can be reduced to sociobiological structures (which again can be reduced to biological structure which

of the features of the field of literature and science, there are still elements that need to be commented on both in terms of the writers and the sources of the field.

Modelling the Field of Literature and Science

In order to get to grips with the overall structures of the field of literature and science, I will argue that it is necessary to take into consideration both the sources and the theoretical approaches and methods of the field, as illustrated in *Figure 2.1*.

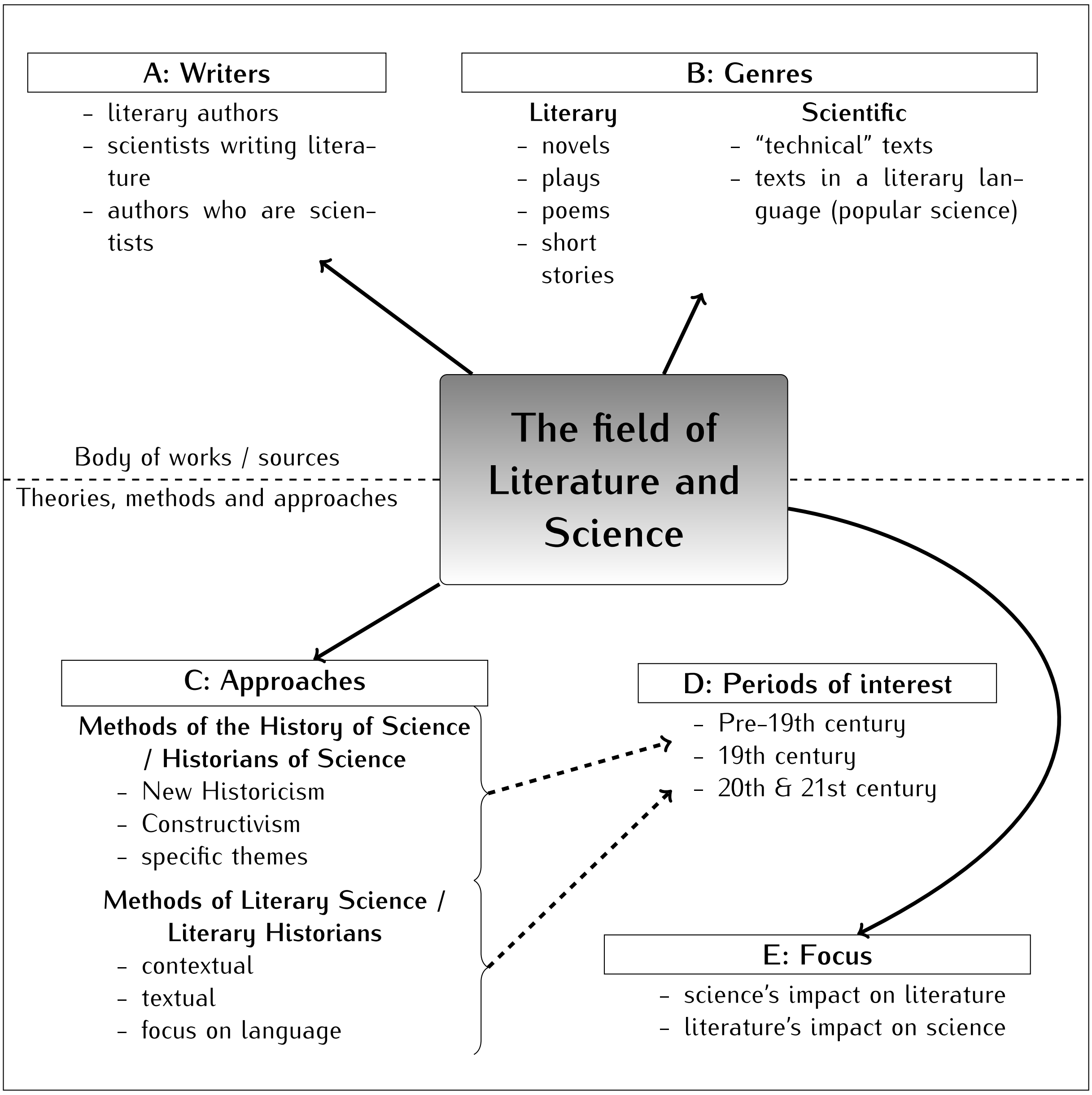

Figure 2.1: Model of the field of literature and science incorporating the sources of the field as well as the theoretical approaches of the writers of the field.

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can be reduced to chemical structures, etc.). The main arguments and history of the Literary Darwinism Movement can be found in the book *Literary Darwinism — Evolution, Human Nature, and Literature* (Carroll 2004), written by one of the central sholars of this field (and indeed one of the few literary historians of the Literary Darwinism Movement), Joseph Carroll.

The space above the dotted line of *Figure 2.1* indicates the sources that the field of literature and science could take into account (there are of course also the individual works, authors, scientists and time periods to take into consideration). In terms of how science has influenced literature, there are a couple of features worth noticing: For centuries, fictional works have been reflecting upon science and the role of science in society in general, either with the notion of satire, excitement or fear (as also illustrated by the first seven categories by Cartwright, see above). The classic example of science as a terrifying venture is Mary Shelley's *Frankenstein*. Some authors have also incorporated various scientific problems and dilemmas in their works of fiction. Other authors have taken up scientific subject matters or ideas, such as evolution and origin, the latter of which is for instance the central theme in Charles Dickens' *Oliver Twist*,.[18] And finally, there are the authors who read scientific writings or were themselves scientists, like for instance Lewis Carroll (1832–1898) was a professional mathematician.

The abovementioned examples also illustrate the fact that the question of genre is very central to the field of literature and science. Is an in-depth analysis of Charles Darwin's use of metaphors a textual analysis of a literary work or an analysis grounded in the history of science? Writers in the field of literature and science often claim, regardless of their own scholarly background, that in order to do justice to both literature and science both disciplines must be integrated in order to create varied and useful analytical tools. But regardless of this point, one should always be aware of the fact that there is a discussion concerned with how science and literature are interpreted in relation to each other: Both with regard to the form of analysis employed (for instance rhetorical analysis) and with regard to the particular theoretical convention (for instance feminist criticism), which brings us below the dotted line of *Figure 2.1*.

Below the dotted line in the figure, the key focuses as well as methods and approaches of the field are illustrated. As mentioned, most writers have focused on science's impact on literature, but whether this is the focus or vice versa, many of the same approaches have been applied. Either when you are dealing with literary or scientific texts as your primary sources, the approaches (cf. C. in *Figure 2.1*) can be used as a starting point for an analysis. The approaches illustrated in *Figure 2.1* are very broad and do not indicate the many different individual methods (for instance deconstructivism[19] or new criticism) that may be used for a detailed reading of the sources. In the following section of this chapter there will be a more detailed account of the particular theoretical and methodological aspects of the constructivist approach.

Moving on to the temporal preferences focused on within the field, it is noticeable that most writers have focused exclusively on nineteenth- and twentieth-century literary and scientific works. The three time periods — pre-nineteenth century, nineteenth century and twentieth century — could very well be placed above the dotted line in *Figure 2.1*,

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[18] Otis 2002, p. xxv.

[19] Cf. Hayles' book *Chaos Bound* (Hayles 1990a) which has a deconstructivist approach to literature and science within the tradition of chaos theory and quantum physics.

but I have chosen to place it below because the choice of time period is, I will argue, closely connected to how the scientific and literary sources are interpreted. As illustrated in D. in *Figure 2.1*, the scholars writing in the field have different approaches to their sources; furthermore their approaches to the texts of the nineteenth and twentieth centuries, respectively, also differ.

In contrast to this aspect, the writers dealing with twentieth-century (and twentyfirst-century) texts in general have a more detailed textual analytic approach and often devise a specific theory or method of analysing on the background of the scientific theories. An example of this is DAVID PORUSH, who in his article "Eudoxical Discourse: A Post-Postmodern Model for the Relations between Science and Literature" sets up a model based on deconstructive theory, quantum mechanics and cybernetics in order to analyse PYNCHON and other literary authors.[20] Many literary writers in the field writing on twentieth-century fiction and science use deconstructivist methods in order to analyse how certain literary works employ modern scientific ideas. In contrast, writers concentrating in nineteenth century texts rarely use the deconstructivist approach. Thus, in many cases there are differences in the literary approach to the scientific and literary texts depending on the period in which the texts were written. In this respect, one will probably not come across a strict deconstructivist reading of nineteenth century texts and likewise PYNCHON's novels will not be subjected to a close reading based on developments in contemporary physics. Furthermore, in the field of literature and science both historians of science and literary critics usually rely on the history of science as well as literary criticism when analysing the different aspects of the field. Therefore, the specific methods of the field of literature and science will always be compositions of already established methods within the history of science and literary history.[21]

2.2 Conflicting Literature and Science

Even though writers in the field of literature and science overall attempt to join the two different disciplines, their differences of opinion sooner or later will appear. In the beginning of the 1990s, when the field enjoyed a period of growth and interest, the so-called 'science war' broke out. Although this science war was not directly aimed at the field of literature and science it still had an impact on the field and its writers.[22] At the heart of the conflict were on the one hand the historians of science — like POUL GROSS, CARTWRIGHT and NORMAN LEVITT — and on the other hand the literary historians — like GILLIAN BEER, SALLY SHUTTLEWORTH, KATHERINE HAYLES, DAVID LOCKE and JEANNE FAHNESTOCK. The war began when GROSS and LEVITT wrote against, among other things, the postmodernist

[20] Cf. Porush 1990.

[21] How critics and historians have analysed literature and science in a nineteenth-century context, I will return to in more detail in Chapter Three.

[22] A special issue of the journal *Social Text*, 1996, addressed the 'science war' when it broke out in the mid-1990s.

analytical methods that had become a more and more accepted (and indeed common) way of interpreting science, which also was the case of the field of science and literature.[23] In addition, Gross and Levitt argued against literary critics and other cultural theorists that wrote on science, but who were not themselves educated scientists. Basically, Gross and Levitt argued that it is wrong to claim that literature and science are equal because this undermines science's objectivity and position as being able to state objective truths about nature.[24] This situation demarcates a clear line between the two different types of writers in the field of literature and science and in addition emphasised the concept of two cultures.

Gross and Levitt's critique was primarily targeted at the many cultural and literary interpretation of science, for instance through the postmodernist interpretation of chaos theory or quantum mechanics. In the case of quantum mechanics, postmodernist theorists have revived Werner Heisenberg's (1901–1976) uncertainty principle. They have interpreted it as the notion that what is known is objective or real, but that it will always be determined by the perspective of the knower. There, they argue, an unstable hermeneutic subject-object relation emerges from where postmodernist analysis can commence. Gross and Levitt's objection to this postmodernist version of the uncertainty principle first and foremost has to do with the basic interpretation of the principle: Heisenberg's uncertainty principle deals with a concrete phenomenon and states that one cannot simultaneously measure the position and the momentum of a particle. In the end, Gross and Levitt believe that postmodernist theorists jump to the conclusion when seeing the uncertainty principle as an expression of the fact that physics cannot provide reliable information about the physical world.[25]

Gross and Levitt's objection to the fact that science and the interpretation of science have become too literary does not mean that the historians of science and literary critics are at 'war' all the time. Both sides represented by the literary critics and historians of science, respectively, agree that science and literature (and other forms of art) can benefit from each other also when it comes to methods and theories. However, the two sides differ when it comes to the central understanding of the nature of science in connection with literature. This difference can be illustrated very concisely by investigating the different constructivist approaches, which are all very widely used in the field of literature and science. First, however, there will be a brief account of the history of constructivism as used in the field.

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[23] One of the books where Gross and Levitt voiced their critique was the *Higher Superstition: The Academic Left and its Quarrels with Science* (Gross and Levitt 1994).

[24] Cartwright 2007, pp. 134–135; Gross 1990, pp. 1–15.

[25] Gross 1990, pp. 42–57; Haack 2007, p. 216.

2.3 Constructing Science

As discussed in the previous chapter, literary scholars have primarily been interested in looking into the ways in which science influences literature. When we look into the influence of literature upon science, it becomes a great deal more difficult to get to grips with apparent tendencies and theories: From the 1960s and onwards the history of science was greatly influenced by various constructivist movements in the humanities, including hermeneutics, semiotics and structuralism. These movements differed greatly from the way in which the history of science had been written up till that point in time: Science could no longer be viewed as a closed entity which developed solely on the basis of an inner logic and a linear progression, as it was claimed by internalist[26] historians of science. The constructivist movements of the history of science encompass a variety of different methodical approaches, theorists and scholarly disciplines, of which only a few will be dealt with in the following.

Taken as a whole, the constructivist history of science wanted to bring other academic fields into the writings of the history of science in order to be able to create new perspectives on science. And thus anthropology, sociology,[27] rhetoric, language philosophy, literary criticism, etc. became an integrated part of how history of science was written from the 1960s and onwards. The main difference between constructivism and previous theories in science historiography was that the constructivists did not see science from a teleological perspective: Science would not move towards a final endpoint, where all knowledge would be revealed. Constructivist history of science thus managed to revitalise science in the context of general intellectual history writing. And giving science a broader intellectual context made room for new ways of analysing science and the language of science.

The philosopher of science Mary Hesse wrote her book *Models and Analogies in Science* in 1963, before the constructivism played a noticeable role in science historiography. Her book was one of the first to take an interest in the role of language and tropes in science, especially metaphors and analogies. Hesse points out that metaphors (literary as well as scientific) have the ability to change the meaning of the scientific ideas. Furthermore, she argues that: "analogies that were created in a specific science can lead to new descriptions of all the aspects addressed in those analogies. These analogical references can conceivably initiate technical, theoretical, and ontological changes in further research".[28] As one of the first, Hesse thus took part in illustrating how scientific language as well as metaphors and analogies in science are a complex system that needs

[26]Internalism claims that science only is affected by itself. By asking and answering questions it is possible to understand and thereby control nature. In the history of science's early years, the internalist approach was widely used (cf. Lauden 1990).

[27]Sociology of science has various positions, amongst which the so-called Strong Program which was the most outspoken and discussed one, devised by Bloor and others. According to the Strong Program knowledge can be explained by the science of sociology, that is, science is primarily a result of how we explain and believe how nature works (Bloor 1991, pp. 3–8).

[28]Naumann 2005, p. 517.

translation. In this respect, some scientists were aware of the role of language in science, which also helped along some constructivist works.[29]

The Role of Language and Literature in the History of Science

In his book *Making Natural Knowledge*, Jan Golinski attempts to determine how scientific knowledge is constructed. He starts out by outlining the history of constructivism in the history of science and goes on to establish what construction signifies in the context of the history of science. In the beginning of his book, he writes that constructivism "regards scientific knowledge primarily as a human product, made with locally situated cultural and material resources, rather than as simply the revelation of pre-given order of nature".[30] Up until the dawn of constructivist views, it had been the general notion that science was a network of "interlinked concepts and beliefs", which signified that new scientific findings were a natural part of the scientific nomenclature at the time.[31]

With the rise of and focus on disciplines like phenomenology, hermeneutics and sociology, the view on science changed. To a constructivist, knowledge and science are both man-made and are results of a cluster of practices that are not necessarily scientific: These practices include the scientific instruments that are used, the environments (for instance the laboratory), the social context and the context in which scientists produce their writings (for instance presenting a paper to fellow scientists versus writing a popular scientific article).[32]

In the late twentieth century, the constructivist history of science started to take an interest in the scientists' use of language — scientists have used and still use many different genres and rhetorical elements in their writings.[33] In the constructivist tradition science is seen as a type of language, and therefore, in this context, discourse analysis is a suitable way of studying science. For instance, can we say that certain entities in science are mere rhetorical constructions with certain attributes? Certain constructivist theorists believe so.[34] In addition to employing rhetorical analysis in scientific writings, we may also take into consideration the fact that primary function of rhetoric is to persuade. One must be able to persuade other people; otherwise your view of the world will be worth nothing. This is also true of science and maybe even more so because it is the general notion that scientific language corresponds more accurately to the 'real world'

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[29]Naumann 2005, pp. 516–517.

[30]Golinski 1998, p. ix.

[31]One of the representatives for this view is Hesse, see above.

[32]Golinski 1998, p. 9.

[33]This notion has been a focus area of the history of science particularly in the past decades. One focal point has been on the way in which practical work in laboratories is also a kind of linguistic entity that corresponds to the language in the writings. This can create translation problems from the materiality of the practical work to the communication of science (Golinski 1998, pp. 103–104).

[34]Gross 1990, pp. 7–8.

than for instance poetic language. And because we consider scientific language to be more objective, we do not tend to see language as constructed and filled with tropes.[35]

An example of the abovementioned can also be found in Golinski's *Making Natural Knowledge.* Golinski has an example that deals with the French scientist Antoine Lavoisier (1743–1794), who in the late eighteenth century attempted (alongside other scientists) to codify the science of chemistry and chemical methods. Lavoisier: "built upon this [the notion of signs or words corresponding to simple ideas] a nomenclature designed to discipline its users so that they would be constrained to accept his own account of chemical composition", Golinski writes.[36] Lavoisier thus wanted to create a certain nomenclature that was linked to his theories, and in the end also linked to the instruments he used, because specific language-use could be used as analogies of the real instruments: "Facts, ideas, and words were related in a chain of representation, in his thinking, and no matter how true the facts or just ideas formed from them, false impressions will result" Golinski states.[37] In this respect language becomes representative of the science and theories that lie behind.[38]

By connecting physical instruments and experiments to a certain nomenclature, scientists became able to make clear in their writings the correspondences between the language and the real world, in the case of instruments. This also helped to establish science's role as a profound and truthful insight in nature because the language of science 'fitted in' with nature. This general nomenclature is therefore also linked to the outlined theory of the scientific text as well as linked to the real world. Because scientists were able to relate their theories to a particular version of the world by using a particular nomenclature, it was also possible for them to link to a specific narrative structure, Golinski argues.

In addition, rhetoric and language are and always have been a big part of science and science communication. As far back as the fifteenth century, the scientific language was renewed, and a more plain objective scientific language emerged and developed alongside the Scientific Revolution.[39] Clear-cut and obvious metaphors and other tropes were no longer a natural part of the objective language; facts should be conveyed as simply as possible. This notion was taken up by the positivists in the late nineteenth century, and has continued to be the dominant view of the scientific language throughout the twentieth century and onwards: The metaphors of science (and scientific writings) today are rare and if they do appear in a text they are usually dead metaphors that do not refer beyond themselves. For the positivists, science is a system of concepts and observational practices with no room for rhetoric. This view of scientific language is a very profound part of the

[35] Golinski 1998, p. 120.
[36] Golinski 1998, p. 118.
[37] Quoted in Fahnestock 1999, p. 172.
[38] Golinski 1998, pp. 118–119; Fahnestock 1999, pp. 172–173.
[39] The establishment of The Royal Society in 1660 also had an impact on the new scientific language. Royal Society published many scientific writings and here the new language was usually employed and thereby helped to establish this new scientific normenclature (Christie and Shuttleworth 1989, pp. 2–3).

way in which most people, including many scientists, perceive science. It was not until the 1960s that theorists like KUHN and PAUL FEYERABEND (1924–1994)[40] challenged the dominant positivistic position. And though some still consider the scientific language as corresponding to the 'real' world, most see that there is more to the scientific language.

KUHN, who achieved academic fame with his *Structure of Scientific Revolutions* from 1962, was against the positivistic view of science. In the same way as the positivists, KUHN saw science and scientific language as systems, but not static systems nor systems that would tell us more about the world than any other system of language. Likewise, KUHN did not have a view on history founded on rhetoric (contrary to theorists like HAYDEN WHITE); rather he looked at the structure and language-use of a particular scientific paradigm. KUHN was interested in analysing the many linguistic aspects of science and argued that science should be looked upon as theory and not merely as empirical facts. This view of science was the starting point from which the constructivists later began their studies of language in the context of, as mentioned, literary devices and literary criticism.[41]

In the following, I shall be looking at the role of literary criticism and literary and rhetorical elements in the history of science in light of the constructivist movements, also taking into consideration some of the works of the history of science which have used literary elements as part of their argumentations.[42] The constructivist theories which I will present in the following will serve as background for creating an analytical model for analysing scientific texts, which will be unfolded in Chapter Three. Therefore, the books and articles referred to below are general methodological works which are not written specifically on literature and science, and which also will be referred to briefly in Chapter Three.

2.4 Three Constructivist Outlooks and Classic Works

When dealing with the field of literature and science there are three principal constructivist approaches to take into consideration. Two of these approaches will be represented and referred to throughout this dissertation, whilst the third only will be briefly mentioned in the following. The three categories are rhetorical studies, hermeneutic studies and semiotic or symbolic analysis, respectively. In the following I will briefly characterise the three modes of analysis and accentuate two classical works that represent the rhetorical and hermeneutic studies, respectively.[43]

[40] Regarding scientific language, FEYERABEND believed it to be closer to poetic language, because meaning is lost in the numerous formulas, rules and mathematical theories of science so like fiction you need to interpret the text in order to get the true meaning (Beer 2000, pp. 84–84).

[41] Golinski 1998, p. 14.

[42] There are, of course, also a number of constructivistic theories that only relate to literature and not to science. But for the purpose of this dissertation, I will only deal with the theories that are relevant in the context of the history and historiography of science.

[43] To the best of my knowledge, contrary to the wealth of rhetorical and hermeneutic studies, no paradicmatic works based on symbolic analysis exist. This circumstance explains why the symbolic analysis is not represented in the following examination of the constructivist approaches to literature and science.

Rhetorical Studies — When Science Controls Language

The first category is *rhetorical studies* and though the name indicates an emphasis on rhetoric, rhetorical studies should not be seen as concrete rhetorical analyses. The basic point of rhetorical studies is that rhetorical elements are linked to the context of science (for instance the audience or particular customs of science), and it is from these contextual marks that science has its starting point. Representing the rhetorical studies are among others historians of science Golinski, Steven Shapin and Simon Schaffer. The rhetorical studies are first and foremost a fruitful way of producing contextual history of science and in the field of literature and science it has mainly been the historians of science and not literary critics, who have carried out these studies. Primarily, there is a focus on the stylistic aspects of the scientific writings and (or) certain historical periods. An example of this is how rhetorical devices function in the context of the Scientific Revolution.[44] One of the most central questions of the rhetorical studies is how it was possible for the scientific language to appear objectively? This question is dealt with by Golinski and to a lesser degree also by Shapin (see below).

In connection with the rhetorical studies it is also important to look into how different scientific norms materialise in rhetorical figures. This also has to do with the boundaries within science; for instance are some scientific principles more 'scientific' than others or is technology a form of applied science? The common notion is that technology is applied science, because 'proper' science is something that takes place at the universities, whilst technology belongs to the industry. This is mainly because the industries in the mid-nineteenth century began to talk about technology as applied science, but this is first and foremost a rhetorical construction, since there are only few scientists that exclusively worked and work in only one field of science and technology.

Rhetorical studies are thus an effective method when writing contextual history of science, because rhetoric deals with convention, situation and most importantly the audience. When scientists have to take their context and audience into consideration the rhetorical studies also will have to focus on this aspect in greater detail than for instance hermeneutic studies (see below).[45] Thus, the rhetorical studies are applied not only in a larger historical context, viewing specific paradigms of science as rhetorical wholes, but also in individual scientists, scientific writings and their rhetorical structure. An example of this can be found in Shapin's article "Pump and Circumstances: Boyle's Literary Technology" from 1984.[46]

[44]Cf. Shapin and Schaffer's book *Leviathan and the Air-Pump* (Shapin and Schaffer 1985), in which they argue how Boyle and his rival Hobbes both attempted to set new standards experimental science in Restoration England.

[45]Golinski 1998, p. 107.

[46]Shapin 1984.

In his article, Shapin deals with Robert Boyle's (1627–1691)[47] experimental work in the second half of the seventeenth century, when he constructed his famous air-pump.[48] The fundamental theme of the article revolves around the question of when and how something becomes knowledge or science. Shapin's focus point is the different forms of truth constructions created through Boyle's scientific experiments but also through the rhetoric. The words and rhetoric that Boyle employs create matters of facts, it is argued.[49] In a nutshell, Boyle was up against the dominating way of producing science, namely the deductive method. Boyle wanted science to be inductive and attempted to illustrate that this method was the best way of advancing science. With this in mind, Shapin looks at Boyle's science and divides it into three categories: the materiel science (that is, the actual construction of the air-pump itself), literary science (the rhetoric that Boyle used in connection with describing the air-pump) and the social science (the literary science applied to a social context and thereby, in the end, creating new conventions). These three elements were true of Boyle's science, but from thereon also became true of most other scientific work, Shapin argues.[50]

It was no coincidence that Boyle wanted his science to have a social context. In the seventeenth century scientific experiments were rare and highly expensive, and thus it was important to have witnesses who could confirm the experiment and make sure that no cheating was involved so you only had to carry out the experiment once. Witnesses[51] and the social context made science credible. And if you had credibility from witnesses and were able to mobilise a social network that supported and confirmed your views, it did not matter a great deal whether for instance an air-pump actually worked or not. But the witnesses were not only present when experiments were carried out they were also present as readers of scientific texts. Therefore, the literary science was also an important part of Boyle's science. In this respect, it was important that scientific texts were accurate, so that it was possible to repeat the experiments, as Shapin notes: "Boyle's literary technology was crafted to secure his assent".[52] In addition, reliable illustrations were necessary in order to show for instance how an air-pump was built. Shapin writes: "We usually think of an experimental report as a narration of some prior visual experience: it points to

[47] Boyle was one of the leading scientists in Restoration England. In his article, Shapin deals with Boyle's *New Experiments Physico-Mechanical* from 1660, in which Boyle among other things describes his invention of a new air-pump (Bowler and Morus 2005, pp. 37, 42–43).

[48] Although the subject matter of the article is not science of the nineteenth century, I have chosen to include the article here firstly because it is a standard word in rhetorical studies and secondly because it points towards central developments in science and literature in the nineteenth century.

[49] Facts are something we all can agree on, whereas we can argue over philosophy. However, in a seventeenth-century context this also had to do with power in the public; Boyle was not educated at the university, but used the conventions of the university-educated scientist to promote his own work.

[50] Shapin 1984, pp. 481–491.

[51] Although one can view Boyle's witnesses as a kind of audience, they were a very small and elite group of people. Thus, the witnesses were not representatives of the common man but usually people with an understanding of science or members of the aristocracy. In the nineteenth century, science became popular and got a new audience (cf. Chapter One) that in some ways took over the function of the witnesses, whether it be as witnesses to entertaining experiments or public lectures or as readers of popular science articles.

[52] Shapin 1984, p. 491.

sensory experiments that lie behind the text".[53] Thus, the whole of the text, complete with accurate descriptions, illustrations and a narrative structure was contributing to constitute the scientific knowledge of the text.[54]

Shapin further points out that it is necessary to have a shared objective scientific language and not have an individual language for every scientific text. Scientists must equally always strive to get this shared language recognised and accepted, and therefore it is quintessential that the language is scientific and objective. In the end, if the text is able to convey reliability and credibility, there will also be established a discourse with a specific use of rhetoric and language, which is exclusively for that particular scientific experimentation. The scientist's role as author also poses various challenges, because the scientific texts: "served to portray the author as a distant observer and his accounts as unclouded and undistorted mirrors of nature"[55] as Shapin writes.[56] The author should thus both present his matters of facts and have his audience in mind when writing the text. In the end, the audience and the social context play large roles in creating the discourse of the particular scientific knowledge:

> The language of early Restoration experimental science was, in this sense, a public language. And the use of the public language was, in Boyle's work, essential to the creation of both the knowledge and the social solidarity of the experimental community. Trust and assent had to be won from a public that might crucially deny trust and assent.[57]

Though Boyle did not write popular science as such, we can see the significance of an audience, because all science must have a social context to become science and must be accepted by the audience, otherwise it is not science. And the narrative structure alongside with the language of the scientific text is where ideas are conveyed.

Hermeneutic Studies — When Language Controls Science

The second method is the *hermeneutic studies*. Hermeneutic studies deal with the significance of different places and time periods, and have mostly attracted attention from literary historians in the field of science and literature. Writers like Beer and Robert M. Young have done hermeneutic studies on Darwin's works, which I will return to in more detail in Chapter Three. In the hermeneutic studies, more focus is given to the content of the individual scientific text and to the relations between texts: One of the central questions of hermeneutic studies is how words and concepts change meaning through time in connection with the introduction of new theories.[58] Another was to look at a specific case (say Darwin and evolutionary theory) developed in a specific context, and then carry out a

[53] Shapin 1984, p. 491.
[54] Shapin 1984, pp. 488–493.
[55] Shapin 1984, p. 497.
[56] Shapin 1984, pp. 494–498, 507–511.
[57] Shapin 1984, p. 511.
[58] For instance the concept of mass did not signify the same to Newton as to Einstein.

comparative study of the case (for instance by looking at the Danish and French reception of Darwin and evolutionary theory). This notion also involves studying metaphors, how they are used and how they came into being.

Beer is one of the most noticeable and most productive writers in the field of literature and science. With her book *Darwin's Plots* from 1983, she established a new outlook on how it is possible to interpret scientific texts on the basis of literary components. Her main argument is that Darwin's scientific writings and theory of evolution were influenced by contemporary cultural expressions, but that they also had an influence on culture. Beer sees Darwin's *Origin* as a work of great hermeneutic potential, that is, the work presents us with a variety of different meanings to interpret.[59]

Beer's approach to Darwin's writing can be divided into three subsections: First of all, she investigates the specific words and tropes Darwin uses. Second of all, she analyses Darwin's theory as: "a form of imaginative history".[60] And third of all, she has a biographical stance on Darwin's writings where she, amongst other things, looks into the style of Darwin's non-scientific writings. This means that Beer does not consider other contextual factors (for instance political or historical) like it was the case with Shapin's analysis of Boyle's works. Beer is only interested in how to create meaning on different levels of the text, from single tropes to theories and general style. Thus, everything is interconnected through a cultural discourse and in the end Beer's approach is a more textual one. Beer's way of viewing Darwin's writing gave rise to criticism. For although Beer emphasises the biographical elements of Darwin's works, she has been criticised (for instance by the historian of science Robert J. Richards) for not having traced the specific metaphors and tropes back to the diaries or other personal writings of Darwin.[61] However, Beer's concern is not to do so, instead she argues that Darwin's tropes and metaphors were an integrated part of the culture at that time, and that it is the use of the tropes in relation to Darwin's theories that is the interesting feature to analyse.

In light of Shapin's article, one can argue that Beer's Darwin is less conscious about his use of language than Shapin's Boyle. Not to say that Darwin, according to Beer, was not aware of the meaning of the language he used, but that the cultural context influenced his use of language. Shapin's Boyle on the other hand created a new rhetoric in his writings that applied to his own particular scientific and social context. These differences between Shapin and Beer's view on language construction thus represent the difference between rhetorical studies and hermeneutic studies. But when it comes to the case of authority, Shapin and Beer agree. As it was the case with Boyle, Darwin also needed to get his message across and establish authority through his works. Contrary to Boyle, the theory of evolution cannot be proven with the use of concrete experiments. Therefore, Darwin only had his language through which he could create authority and establish facts,

[59] Beer 2000, pp. xxiv, 8.
[60] Chapple 1986, p. 156.
[61] Richards 2003, p. 35.

which was also the case of a number of nineteenth-century scientific theories.[62] DARWIN was also aware of his audience as he showed when he in the beginning of *Origin* stated that he was writing to the 'educated reader', and thus not for the scientific community exclusively. Even though authority might be established more substantially by addressing other scientists, DARWIN made the choice also to communicate his theories to the general public.

However, according to BEER, writing to the educated reader also posed challenges for DARWIN. BEER identifies four problems DARWIN which had in interlocking his theories and language as he did: DARWIN's first problem was that language by nature is anthropocentric and therefore man is always the centre of signification. Secondly, language always has an agency. DARWIN's theory "depended on the idea of production. The natural order produces itself", as BEER writes.[63] Thirdly, DARWIN wrote against the discourse of natural history, which in that period of time was still influenced by ideas stemming from the language of natural theology. And lastly, as mentioned, DARWIN faced the challenge of addressing both professional scientists and the educated reader using the same language.[64,65]

The various considerations about the nature and meanings of language create an awareness of how narrative structures and tropes influence scientists and their science, and how they in return construct new meanings that are adopted into the general culture. With *Darwin's Plots*, BEER helped establish the hermeneutic studies as *the* literary approach to scientific texts. Indeed, the many hermeneutic studies have proven fruitful analytical tools in dealing with the interrelations between literature and science, but this also poses problems to those historians of science who do not accept that science is fundamentally governed by language.

Semiotic or Symbolic Analysis — When Science is Symbols

The third and last category of constructivism that I will mention briefly is the *semiotic or symbolic analysis*. Symbolic analysis, like rhetorical analysis, considers the contextual aspects of the scientific texts. We have to understand the context in order to understand scientific ideas, and in this respect we might look into semiotic premise of relations between objects and signs. This notion stems partly from FOUCAULT's thesis on the relation between sign and object according to which no apparent correspondence between signs and the objects they signify have existed since the mid-seventeenth century. This ontological gap points towards the fact that signs are interchangeable.[66] Symbols can be interpreted not only in terms of their historical development — the meaning of the symbols changes throughout history — but also in relation to the differences between the various

[62] Beer 2000, pp. 49, 75–76.

[63] Beer 2000, p. 48.

[64] Beer 2000, pp. 47–49.

[65] A detailed analysis of DARWIN's language will be carried out in Chapter Three, where this discussion also will be dealt with.

[66] Golinski 1998, p. 152.

scientific disciplines, where a symbol may signify one thing for a physicist and another for a biologist.

The symbolic analysis also has to do with coining of words and concepts, Golinski writes:

> The unit of resistance (the "ohm") was *defined* in absolute mechanical units as ten million metres per second. That unit then had to be *realized* in practice in Maxwell and Jenkin's spinning coil experiments in the mid-1860s, which produced a coil that could serve as the *representation* of the standard.[67]

Thus the unit of ohm meant something different in different countries and different scientific communities at a certain point in time. Symbolic analysis thus is based on individual words and the particular object (or units of measurement) they denote. Contrary to this, rhetorical and hermeneutical studies deal with different interpretations of various concepts, language and rhetorical structures in different contexts. Several writers in the hermeneutic and rhetorical tradition have used elements from symbolic analysis, and hence some of the works that will be dealt with throughout this dissertation will include references and perspectives from the symbolic analysis approach. But since few works represent the symbolic analysis approach exclusively, the following chapters will mainly refer to works within the rhetorical and hermeneutic approaches.

When Language Hits Science

The rhetorical and hermeneutic studies by Shapin and Beer, respectively, are examples of two different constructivist approaches to the relations between science and literature. Furthermore, the two approaches usually separate the literary critics and historians of science writing within the field of literature and science. Essentially, the rhetorical studies approach views the scientists as being in control of the language used in their writings. The hermeneutic studies approach, on the other hand, sees language as the principal controller. These two very different views will inadvertently create opposition between certain historians of science who do not believe science as such consists of and is dominated by language. In comparison, literary critics are probably more likely to approach science as a form of language, which opens up for a variety of interpretations.

If we return to Shapin and Beer's analyses, their different takes on the relations between language and science also generate further perspectives on the science-text dichotomy. Shapin shows how scientists in the late seventeenth century slowly became aware of how scientific ideas and inventions could (and also to some extent should) be communicated. Creating a particular objective scientific language, promoting authority and being conscious of your audience were all aspects of the scientific disciplines, which from then on became crucial to science communication. Beer's analysis of Darwin also includes the abovementioned aspects, but in the latter half of the nineteenth century,

[67] Golinski 1998, p. 175.

narrative structures had also become an important element to take into consideration for scientists. Rhetorical and hermeneutic studies and analyses are therefore essential as theoretical examples and individual case studies in a nineteenth-century context, as illustrated in the following chapters.

It is clear that the three different approaches to literature and science are fruitful each in their own way. Roughly, one can say that the rhetorical analysis is the more contextual approach, the hermeneutic places itself between the contextual and the textual levels, and the symbolic analysis only lies on the level of language. All three approaches have been used in connection with analysing nineteenth-century literature and science.

2.5 The Field in Perspective

In this chapter, I have outlined the basic elements of the field of literature and science with the main emphasis on the constructivist part of the theories used in the field. Since the field is influenced both by literary criticism and the historiography and the history of science, great many different elements constitute the interactions of literature and science. In order to establish a model for analysing literature's impact upon scientific texts it is clear that it is important also to have a theoretical and historiographical base in addition to having a contextual and textual groundwork. The contextual and textual groundwork have to do with the historical and cultural context of the text, and the structure and contents of the text, respectively. Both subcategories in the field of literature and science deal with the level of historical and cultural context as well as the textual level. I will argue that one of the ways to construct a useful model for analysing scientific texts is by combining the rhetorical and hermeneutic approach, as will be illustrated in the following chapter.[68]

The field of literature and science naturally presents a variety of differences and conflicts. Not only are the textual sources taken from very opposite fields, but the writers analysing the texts also have conflicting approaches to science (and literature). In the following chapter, the conflicts between the literary critics and the historians of science in the field will resurface several times. In my opinion, both the literary theorists and the historians of science present valid and interesting analyses of the relations between science and literature, but in order to do justice to both literature, language and science it is necessary to consider the many different contrasts, perspectives and approaches that are present in the field of literature and science.

[68]It is, of course, possible to make combinations that are not based on constructivist theories, but for the purpose of this dissertation I will not focus on these.

Chapter Three

Devising a Literary Model for Analyses of Scientific Writings

> Here lies nipped in his narrow cyst
> The literary contortionist
> Who'd prove and never turn a hair
> That Darwin's theories were a snare
> He'd hold as true with tongue in jowl,
> That Nature's geocentric rule
> . . . true and right
> And if one with him could not see
> He'd shout his choice word 'Blasphemy'.
>
> Thomas Hardy "Epitaph for G. K. Chesterton"

It has often been argued that Victorian fiction, including the realistic and naturalistic literary movements of the late nineteenth century, were inspired in style and content by science and scientific texts. As mentioned in Chapter One, this inspiration from science was visible in many different ways in works of fiction, especially when it came to authors who knew about and were interested in science like George Eliot and Thomas Hardy. Furthermore, obvious scientific and positivistic elements in many works of fiction in the period were likewise inspired by the contemporary literary movements and literary elements in general.

It has yet to be explored the full extent of which scientists sought inspiration from literature and literary authors. Scholars have acknowledged that a great many scientists have been inspired by literature and use literary element consciously in their scientific writings. There has, however, not been an attempt to set up a general analytical model that can be used on the scientific texts. Instead, the focuses have been on individual scientists or individual scientific texts, which usually are analysed with the emphasis on a contemporary cultural context. As discussed in the previous chapter, most writers in the field of literature and science focus on science's influence on fiction and not vice versa. In my view there are two primary reasons for this. Firstly, most of the writers in the field have a background in literary history and criticism and hence their field of expertise is fiction. Secondly, when dealing with science in fiction, literary critics often approach these fictional works like any other fictional text and thus employ textual analysis and other literary critical approaches without considering the history or historiography of science in detail. To the best of my knowledge, few, if any, concrete models exist for analysing science and scientific texts in the view of literary structures integrating elements of the history of science and literature. Hence, most writers have only focused on one or few scientific texts (and scientists) and therefore the analytical strategies also have been very individual.

In this chapter, I will outline an analytical model from which scientific texts may be analysed in order that the literary components and structures may be considered. The model will depart from two starting points. Firstly, it integrates a general literary and textual analysis approach to a text. And secondly, the structure of the model will rely on the various viewpoints that have been raised by theorists within the field of literature and science in dealing with literature's influence on science, who both consider the literary field and the historiography of science. Taking both sides of the field of literature and science into consideration, it will be necessary to select key elements from the many works written on the relations between science and literature. Naturally, there are limitations to such a model and it will not be possible to include all aspects, but I believe that my selection is representative of the aspects that are present in the discussions on the relations between literature and science. Additionally, it will be necessary, to some extent, to customise the analytical model to the subject matter at hand. Thus, there will be some variations (especially when it comes to the level of language, last in this section) from the model in this chapter dealing mainly with evolutionary theory as opposed to thermodynamics, which will be dealt with in Chapter Four.

The analytical model will be constructed from the constructivist-based works on the interrelations between literature to science within the field of literature and science. Not only has the constructivist movement been particularly conscious of the impact of literature on science, but it also suggests how scientists in the nineteenth century were conscious of literary elements in their scientific work. Moreover, I believe that both sides of the field of literature and science should be taken into consideration, as well as taken into consideration both the agreements and disagreements between the two sides of the field. In this way, it will be possible to discuss both sides of the field, integrating different perspectives on the science writings.

I have chosen to use one case study around which to construct the model. At the heart of the case study are the works on the literary influences on CHARLES DARWIN's works, in particular *On the Origin of Species* (1859).[1] In order to further exemplify how the literary devices are used, T. H. HUXLEY's popular science article "On a Piece of Chalk" from 1868 will also be used as a reference point. HUXLEY was a great devotee of DARWIN and his evolutionary theory, and HUXLEY himself used the evolutionary structures of narrative in his works, including this article on chalk which presents key issues of evolutionary theory.

[1] I will mainly deal with *Origin*, since this is the book that is the primary interest of most of the books and articles that I refer to.

Huxley's article was originally published in *Macmillan's Magazine*,[2] a journal of general interest. The article is a transcript of a lecture, which Huxley gave at a meeting of the *British Association for the Advancement of Science* for a group of workingmen.

This case study will both broaden the discussions in the various parts of the model and also illustrate how writers in the field of literature and science have dealt with literary structures in relation to nineteenth-century evolutionary theories, in this specific case of Darwin and Huxley. The reason why I have chosen the Darwin-case as the central case of this dissertation is because Darwin's works and evolutionary theory in general have been the main focus of the writings on literature and science in the nineteenth century since the beginning of the 1980s. The Darwin-case has been investigated excessively and therefore is the best representative of the relation between literature and science in the nineteenth century. Only in a few cases, writers have taken an interest in scientists and scientific theories other than Darwin and evolutionary theories. Within the last decade, however, the interest in nineteenth-century connections between literature and science has shifted to, for instance, thermodynamics which will be treated in Chapter Four. Because the Darwin-case is very central to the field of literature and science, many of the writers that will be referred to in this chapter have already been mentioned in the previous chapter.

The analytical model will be composed of three levels (with various sub-categories), see *Figure 3.1*. In setting up the analytical model, it has been necessary to make a pragmatic selection of which and how many literary elements to include in it. My pragmatic solution has been to primarily focus on the elements that are used in the existing scholarship on Darwin and evolutionary theory. The three levels of the model are: a biographical level, a textual level and a level of language and tropes. The three levels cannot be treated in sequence, so throughout the analytical model they will overlap and a few repetitions are likely to occur. In some cases a subcategory will be relevant only to the specific case of Darwin, but I have chosen to incorporate some of these subcategories at any rate, in order to get to a complete understanding of the relations between literature and science in the scientific writings of Darwin and the evolutionary theory. In this respect, Darwin and Huxley's texts will not categorically show how scientific writings and genres embraced literary elements, but the examples will be the basis of a discussion of the literary elements of the model and will be used to put into perspective the case of thermodynamics in the following chapter. In the following section, I will briefly comment on how Darwin and evolutionary theory in general have been dealt with in the field of literature and science.

[2] Chapple 1986, p. 9.

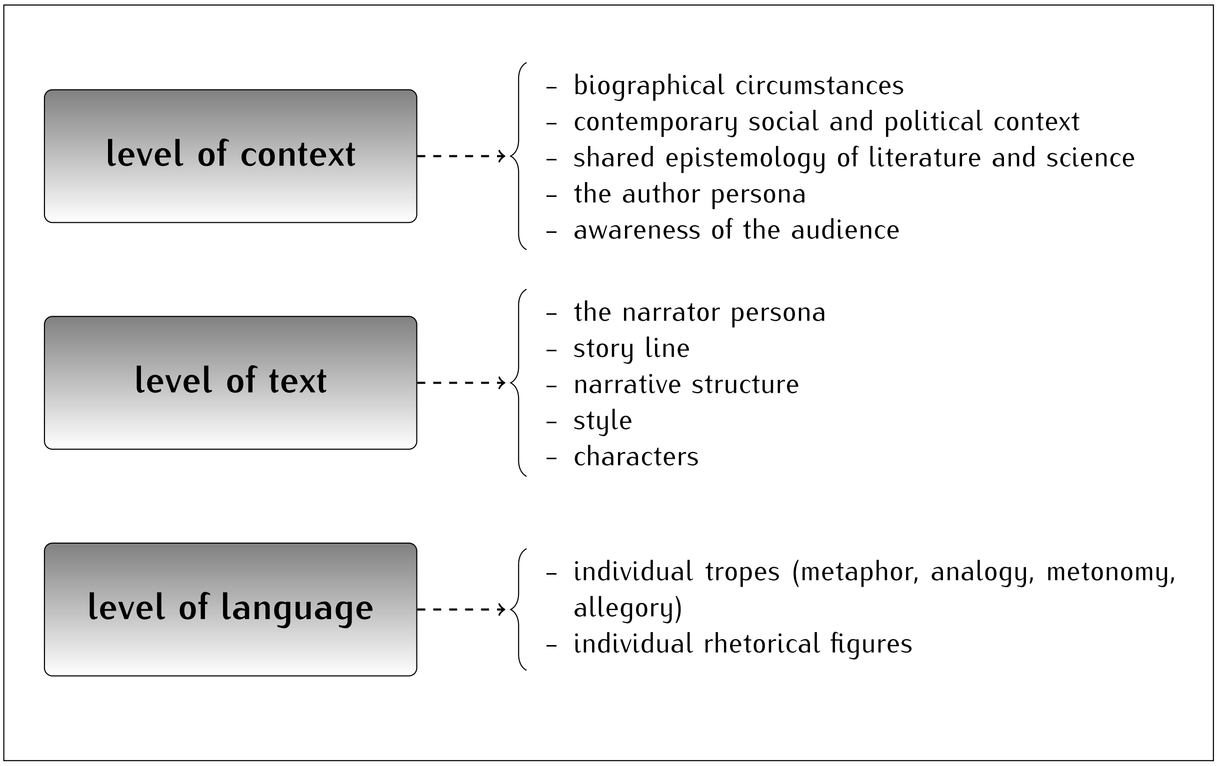

Figure 3.1: Outline of the structure of the analytical model consisting of three levels of context, text and language.

3.1 Evolution According to the Field of Literature and Science

The writers dealing with Darwin mainly belong to the hermeneutic tradition of the constructive section of the field of literature and science field, and additionally most of them are literary theorists. As previously mentioned, Gillian Beer and George Levine, two of the most noticeable writers on the literary elements in Darwin's works, see science as a cultural discourse, which is the main assumption in *Darwin's Plots*, first published 1983, by Beer and *Darwin and the Novelists*, 1991, by Levine.[3] Both critics and much of their work on literature and science have been described as deconstruction, because they view science as a cultural discourse that in the end is seen as consisting only of signs and language.[4]

In Levine's *Darwin and the Novelists*, the main focus is on how Victorian authors were influenced by Darwin's works and thus Levine has his main emphasis on how science influences literature, as well as how Darwin's narratives translate into a realistic and naturalistic Victorian narrative. In addition, Levine dwells on how the various dichotomies in the period play a part in both literature and science: Microcosmic narratives versus macrocosmic narratives, evolution and gradualism versus revolution, observation versus

[3] Beer 2000; Levine 1991.
[4] Locke 1992, p. 176.

experimentation, etc. In LEVINE's interpretation of the role of the narrator and the role of various aspects of the narrative, he presents a number of different ideas that also can be viewed in relation to the influences of literature upon science, as will be presented in the analytical model below.

BEER's book on DARWIN's plots is mentioned briefly in Chapter Two, but to the end of establishing an analytical model it is worth looking further into BEER's work: In the preface to the second addition of *Darwin's Plots* she writes that it is not her intention to present DARWIN's *Origin* as a piece of fiction, she claims only that the non-technical style employed by DARWIN allowed the educated reader to read the work and interpret different meanings from it.[5] BEER develops this notion further in another article, where she explores how language theory is connected to evolutionary science and she sees linguistic theory as an indication of the evolutionary processes presented in DARWIN's work. This may be viewed as a somewhat extreme reading of science, because it presents science as dependent of and, to some extent, formed by language.[6]

As mentioned in Chapter Two, BEER outlines four main problems in connection with precipitating DARWIN's theory as language: First of all, two general problems can be encountered in any form of discourse, namely the fact that language is anthropocentric and language will always include agency. More specifically, DARWIN's discourse is inherited from natural history and he has to address a general readership.[7] These four problems, which will be dealt with in detail below (the two latter in the first section and the first two in the last two sections), are prime examples of how science is viewed as a form of language and whose primary difficulties have to do with language and not the concrete science communicated in the text.

A less extreme viewpoint of the literature-science relationship is found in ROBERT M. YOUNG's collection of essays entitled *Darwin's Metaphor* from 1985.[8] In his book, YOUNG concentrates mainly on one metaphor, namely DARWIN's concept of natural selection and how this metaphor evolves through *Origin* and in the end symbolises all evolution in nature, and thereby the single metaphor encompasses DARWIN's theory as a whole. YOUNG sees DARWIN's metaphor of natural selection as anthropomorphism, as is also the case in BEER. Nature is humanised, because we cannot say for sure who is selecting: God, man or nature? Hence, the metaphors are open to interpretation, which presents yet another notion because DARWIN did not have a full understanding of how his works and thereby his metaphors would be interpreted by the reader: The moment DARWIN's works were published he would lose control over his metaphors, YOUNG argues.[9] For YOUNG, both the readers and the general cultural context add meaning to the metaphor.[10] BEER has

[5]Beer 2000, p. xxv.

[6]Christie and Shuttleworth 1989, pp. 14, 158, 164.

[7]Beer 2000, pp. 47–49. See also Chapter Two, p. 35.

[8]YOUNG places himself in a Marxist tradition, but many critics have described his works as deconstructivist even though YOUNG himself does not consider his own work as such.

[9]Golinski 1998, pp. 124–126.

[10]Young 1985, pp. 122–125.

criticised Young for only looking at one metaphor in isolation and not the interplay of the metaphors within the text. Beer furthermore notes that Young is moving away from the notion that science is not an exclusive domain separated from society.[11] Thus, Young's approach to Darwin is leaning more towards the concept of science as being part of society as opposed to science being viewed as a specific type of language.

Not all articles on Darwin within the field of literature and science have been written by literary theorists or are hermeneutic studies. Quite a few historians of science have dealt with Darwin and the literary link, most noticeably Alan Gross in, for instance, his *The Rhetoric of Science*, 1990.[12] Gross' take on Darwin is, not surprisingly, far more contextual than seen in Beer, Young and Levine. Furthermore, Gross' overall take on science is that it refers to the real world and not just language. In his rhetorical study, Gross argues that one can see how Darwin's theory of evolution developed by looking at the progress and structure of his notebook. Thus, Darwin's creative process is an inner rhetorical process and manifests itself when he learns new facts and discovers new things, according to Gross.[13]

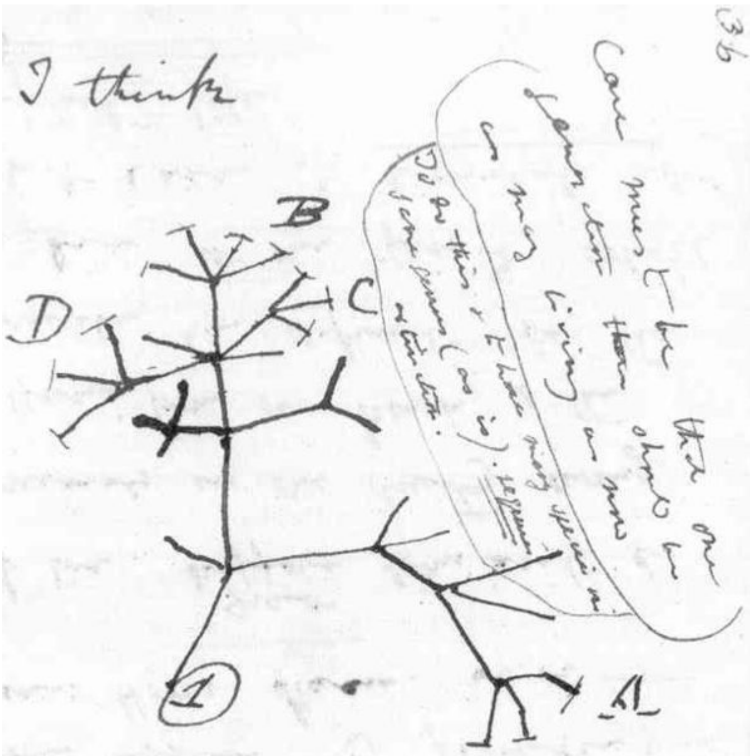

Figure 3.2: Darwin's *first evolutionary tree, from his notebook written whilst on the voyage with the Beagle, 1837. Above the tree he has written: "I think". This thought was part of what later developed into his complete theory of evolution. See Figure 3.5. (Source: Wikimedia).*

As mentioned in the previous chapter, Gross and other historians of science writing within the field have criticised literary historians like Beer and Levine; as historian of

[11] Beer 2000, pp. 83, 89.
[12] See Chapter Two.
[13] Gross 1990, pp. 148, 159, 194–195.

science Robert J. Richards writes: "What is missing from their work is an effort to trace back a metaphor, a turn of phrase, or an imaginative trope to Darwin's notebooks, essays, and letters, in order to catch these figures as they first emerge".[14] Looking only at the scientific context is far from sufficient to construct a thorough analysis of the work, it is argued, instead a more thorough biographical approach is needed. This fundamental conflict between the historians of science and the literary critics is not just concerned with how the scientific works should be approached, but is also a question of how the period is seen and how the epistemology of science and literature is regarded.

The Epistemology of Scientific Writings

The positivistic movements of the mid- and late nineteenth century contributed significantly to move the scientific writings towards a more objective language. Modern day scientific writings have adopted and enhanced this style concerned with communicating scientific facts and theories: The language of the writings is formal and above all objective. In his book *Dying to know*, Levine sets out to investigate the question of epistemology in relation to the way people have constructed narratives focusing especially on the epistemological relations between nineteenth-century literary and scientific writings. According to Levine, both nineteenth-century literary and scientific narratives shared the same epistemology, that is, scientists and authors were 'dying to know', as it were. This search for knowledge has always been a fundamental fact of human existence, but resulted in a new expression in nineteenth-century scientific writings. This existential search for knowledge was a substantial part of the empiricism that had characterised science in the Western world since the Scientific Revolution, and by the nineteenth century it had established itself as a fruitful way of ascertaining knowledge.[15]

In the introduction of his book, Levine points out that novels and narratives in general often are structured by questions of justifiable beliefs, like: 'Did the protagonist get it right?' and 'Why was the protagonist betrayed?'. In the context of the mid-nineteenth century, these characteristics can be seen especially in the *Bildung* narrative, he argues.[16] The development in the novels and the bildung process the protagonist goes through are both equivalents to the quest for knowledge, found in the scientific writings. In dealing with nineteenth-century science, it is, according to Levine, important to note the difference between science as objective (that is, the objective facts that can be found out through observations and experiments) and science as justifiable beliefs (that is, the belief that science is objective and can describe things objectively). Hence, the justifiable beliefs are present in both science and literature, according to Levine.[17]

On the likeness between the scientific and literary narrative Levine writes:

[14] Richards 2003, p. 35.
[15] Levine 2002, pp. 1–2.
[16] In this context, Levine emphasises works of Dickens, Eliot and Hardy.
[17] Levine 2002, pp. 10–11.

> They [the protagonists of the literary stories] are not singular, I am certain, in believing that their own interests are not among the bad ones. Narratives dramatize the likelihood that if everyone else's interest is in bad faith, so, too, is the protagonist's likely to be [...] there is something to be learned from watching the ideal of objectivity at work, not through the strong arguments of philosophical 'realists' [...] but by feeling the pressure of 'truth' embodied, as novels in particular embody it, by people. The narrative of scientific epistemology folds neatly into the narratives that dominated English literature and culture in the nineteenth century, evidence that the ideal of epistemological disinterest or self-sacrifice or self-annihilation had managed to permeate the culture's consciousness.[18]

Hence, in both fiction and scientific works the shared epistemology shines through. Additionally, LEVINE also addresses the difference between objectivity as fact and objectivity as beliefs. These shared features of science and literature, which in LEVINE's view also includes features like discovery, construction and disinterest, in many ways resemble the features of the positivistic worldview, but according to LEVINE, his version of the scientific epistemology is more nuanced and argues for similarities on a narrative structure. With LEVINE's epistemology it becomes the narrative structure which is a central element, and something that is often been paid no or little attention to by the critics in favour of the positivistic view.[19] Furthermore, LEVINE emphasises the subject matter of the text. Whether it is a scientific or a literary text, the subject gets to play an important part in contrast to texts of a positivistic style, in which the subject is largely disregarded.

Approaching DARWIN in the context of LEVINE's views on epistemology, one might ask the same question as BEER does in one of her articles on DARWIN: "How far did Darwin figure himself as creating what he describes"?[20] Thereby she is pointing out that DARWIN was conscious of his own writings as a creation in a specific context. Both BEER and LEVINE see science as inseparable from contemporary cultural contexts; science merely had a larger share in the epistemology in the mid-nineteenth century and was therefore able to substantiate certain stylistic aspects that connect the scientific and literary narrative. LEVINE and BEER's take on the shared epistemology of science and literature, and indeed scientific and literary writing, means that they also analyse a scientist like DARWIN on the basis of this. If one regards Victorian scientists as conscious of their part in a shared epistemology with the current literary and cultural movements, it will be a lot easier to see the narrative structures of scientific writings as a parallel to the fiction.

In his book *The Rhetoric of Science* GROSS argues, like LEVINE, for a separation between science as finding objective facts and science reproducing these facts. To GROSS, the latter does not entail justifiable beliefs but has to do with the rhetoric of science. In the case of DARWIN and the theory of evolution, the facts revolve around the species and a specific taxonomy of these species, which is at the core of evolutionary theory,

[18] Levine 2002, p. 12.
[19] Levine 2002, pp. 13, 23–24.
[20] Beer 1986, p. 242.

This taxonomy, however, is not 'out there' in nature, but only exists textually and in the evolutionary rhetoric. Contrary to BEER and LEVINE, GROSS argues that DARWIN's works and their rhetoric were independent of the period. This means that DARWIN's analogies, metaphors, etc. are not disregarded as time goes on, but help expand and mature the theory of evolution beyond DARWIN's own time. To GROSS, the epistemology of science is not bound by the contemporary society but lies in how science is arranged and structured. Therefore, GROSS also argues for another approach to the study of the nature and rhetoric of science. Since the process of DARWIN's discovery is independent of a shared epistemology between science and culture, one should look into DARWIN's diaries to investigate the development of his rhetoric and style that ends up constituting an evolutionary taxonomy.[21]

Therefore, a fundamental difference exits. On the one hand, one can view the epistemological grounds of science as a part of a general cultural context where the scientist is conscious about his role. On the other hand, one can claim that scientists are not as conscious of their writing and that science, in itself, sets the boundaries for what it is and is able to do. In this respect, the reference to a general cultural context is only stylistic. This conflict remains intact when looking closer into the specific case of DARWIN and evolutionary theory, and it has a fundamental influence on which aspects of DARWIN's work are emphasised.

3.2 The Contextual Level — Author and Authority

Who, what and to whom are typically the first questions we ask when reading any type of text including scientific texts: In this first section I will look at the biographical and contextual level of the scientific writings. On this level, the intention is mainly to look at two aspects, the author and the narrator. Obviously, there is a somewhat uncomplicated way of investigating whether a particular writer has been directly inspired by a particular literary work.[22] However, this is not particularly relevant for this dissertation since it does not primarily concern individual scientists and their private and social experiences with particular fictional works and this will therefore only be referred to when relevant. Even though the biographical circumstances will not be scrutinised, it is worth drawing attention to the fact that the biographical lives of the scientists are also embedded parts of the conflict between literary critics and historians of science in the field of literature and science. Historians of science in the field, like GROSS, have argued that the biographical circumstances of the scientists are an important factor when dealing with scientific texts, whilst literary critics, amongst them LEVINE, do not emphasise the biographical lives of scientists (see below).

[21] Gross 1990, pp. 17–18, 48–49.

[22] This has been done in some works written mostly by historians of science in the field of literature and science, as mentioned above.

In addition, very few authors of fiction and works can be said to have had a direct influence on scientific writings, like for example John Milton's *Paradise Lost*, is known to have influenced the writings of Darwin.[23] But these fictional works from which scientists sought inspiration have mainly been seen as reference points or for emphasising specific metaphors in the scientific text. Therefore, they were not used in order to create a particular style of scientific writing. Thus, in this case it is not the contextual level understood as the biographical or social circumstances surrounding the particular scientists and his scientific body of work. The aim of this part of the chapter is to analyse how the scientists chose to formulate their ideas and findings in their writings. Hence, the key issue has to do with how the discoveries and arguments of the scientists are structured into a narrative. As Levine writes in one of his essays on Darwin:

> *Origin* begins with Darwin describing how he was 'struck' by a point and then 'driven to conclude'. The location is no accident but a stylistic choice representative of Darwin's scientific method, a method that entails the irrelevance of personal style.[24]

Thereby Levine denounces the representation of the genius scientist and instead describes Darwin as conscious of his scientific undertakings.

In the following, I look into three different aspects of the contextual level, mainly concerning the scientist as author. Firstly, the epistemological level of the scientific texts is significant, just as any other literary work: How the scientist, as any other writer, considers the epistemology of his written works. The second aspect of the contextual level has to do with the question of whether there is an awareness of the scientific texts communicating a particular worldview. And whether there equally is an intention of the audiences addressed. These last two issues are linked to the epistemological aim of the scientific text, but contrary to the epistemology of the texts, getting a particularly message across to an audience demands a great deal of literary considerations on the part of the author. Hence, the scientist's conscious intention with his writings will be communicated and supported through literary structures in the texts.

The Audience and the View of the World

The next aspect of the framework is meant to capture the individual scientists' awareness of their audience as well as the message of the texts they produce. Assuming for the sake of the argument that there is a shared epistemology between the scientists and their audiences, the individual author strives to present his particular scientific worldview in a way that his audience will be likely to appreciate. On the same notion, one may address the question of whether and to which degree the scientists are conscious of the usage of

[23] Darwin brought Milton's book with him on his voyage on the Beagle in 1831, and a number of scholars have argued how the inspiration from Milton can be seen in Darwin's works (see for instance Beer 2000, pp. 26–27).

[24] Levine 1993, p. 385.

literary elements when communicating their science to a general audience. Throughout the nineteenth century, the scientific way of viewing the world became increasingly dominant. Although religion still played a large part in many people's lives, including many scientists', the religious image of the universe was gravely threatened. In the course of the century, the natural sciences rose from being an amateur's leisure pursuit to being professional disciplines. In addition, coherent narratives of science in the period began to challenge the religious narrative as a more accurate view of the world.

Scientists brought these coherent narratives into their writings to form a cohesive scientific knowledge of nature, partly in order to strengthen the identity of the specific scientific disciplines. In the beginning of the nineteenth century scientists wanted nature to give them all the answers, later they learned that the experiences they had within the scientific community were just as vital a part of the communication of science. Matters of fact and the laws of nature began to be viewed, to a certain degree, as human constructions.[25] Indeed, the communal experiences became part of the scientific writings, as will be exemplified below.

As mentioned previously, Steven Shapin points out in his article on Robert Boyle,[26] that experimentation helped create a new objectivity and authority in the scientific writings. But scientists of the nineteenth century needed tools that could transform their experiments into cohesive narrative structures in order to uphold and establish even more authority. Descriptions of experiments and observations and empirical evidence could no longer stand on their own, neither within the science communities or outside. Indeed, the scientific narratives became inevitable, as some scientists, like for instance Darwin, did not base their theories on empirical facts or experiments. In the end, the various narratives (for instance those of evolution and thermodynamics) needed to achieve or rather create a believable and valid storyline that could help further the scientists' theories in relation to the public.

In his analysis, Shapin also deals with the scientists' awareness of their audience. Science, according to Shapin, has to do with convincing other people, both other scientists and the general public. And science needs to be connected to the world outside science in order for the audience to understand the scientific argumentation. This is indeed important when writing popular science, and as this genre became more and more common and widespread throughout the nineteenth century the audience awareness also became increasingly significant for the scientists. The works of Darwin serve as a prime example, as does the article by Huxley which I will discuss first. Huxley's article highlights the aspect of audience awareness as well as conveying a particular worldview.

Huxley's "On a Piece of Chalk" was written as a popular science article and demonstrates in many ways that the author was very attentive to his audience and his scientific message. This perhaps also has to do with the fact that the article was originally a public lecture. Likewise, we find a notion of authority in Huxley's text based on indications

[25] Levine 2002, p. 257.

[26] See Chapter Two, p. 31.

rather than concrete facts: Upon asking the question of where chalk originates from and why it is so widely spread, Huxley writes:

> You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than a "piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.[27]

Accordingly, Huxley has no problem by stating that his arguments may not be as empirical as one might expect from a scientific article. He then goes on to write that the aim of his article is to state something about the nature of the world. Huxley has a particular story, or theory, to present to his audience, and he needs to guide them to a greater understanding of this theory. He writes: "Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe, which I hope to enable you to read, with your own eyes, tonight".[28] In this quotation, and continually through the article, Huxley leads his audience towards a better understanding by means of their own imagination and intellectual capacity.

Huxley's matters of facts are likewise highly indicative: The audience must together with Huxley 'discover' the history of chalk. In this respect, the audience plays a vital role in the communication of scientific knowledge. The authority one might expect a scientist like Huxley to have is absent, and instead authority is created together with the audience and their taking part in uncovering Huxley's arguments and theory. Thus, to some extent, Huxley claims authority not through facts but through the evolutionary narratives established primarily by Darwin. However, Darwin's works, as mentioned, were not based primarily on empirical facts but by observation and the claim that nature itself, and not God, would be the evidence of evolution.[29]

This element of discovery is one of the more striking similarities between Huxley's article and Darwin's *Origin*, and in this respect Huxley's storyline bears resemblance, in structure, to a detective story: The reader is invited to try and trace the origins of chalk alongside Huxley as the scientific and authoritative guide. Huxley writes: "We all know that if we 'burn' chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas, and lime, and when you make it very hot the carbonic acid flies away and the lime is left".[30] Here, Huxley pays attention to the fact that his audience is not a scientific one. Hence, his scientific investigation is based on a non-scientific knowledge that his readers

[27] Huxley 1909, p. 31.
[28] Huxley 1909, p. 31.
[29] Levine 1991, pp. 8–9, 210–211.
[30] Huxley 1909, p. 32.

posses. This notion may stem from Darwin, whose *Origin* has been characterised as a kind of detective story by amongst others Beer and Levine.[31] Indeed, in the beginning of the *Origin*, Darwin proclaims that he will study domestic animals and plants, because they will give the best clues on how evolution works. Thus, Darwin makes it immediately known that there is something to be uncovered on the basis of nature's observable clues.[32] Levine writes on Darwin that: "[H]e seemed to piece his story together, like a detective in a literary genre that owes much to science, through fragments and traces, building vast structures from seeds and spores and insects and fossils".[33] Likewise, Huxley traces the origins and distribution of chalk and in the process uses his audience as co-discoverers.

In the end of Huxley's article, the final discovery is that chalk can be seen as a proof of evolutionary theory, and Huxley concludes that: "A small beginning has led us to a great ending".[34] The insignificant piece of chalk has thus grown into an elaborate narrative, ending in a scientific proof of evolution. At the end of his article Huxley furthermore maintains the claim that scientific narratives are far more reliable than any religious narrative on the creation of nature. He writes:

> Choose your hypothesis; I have chosen mine. I can find no warranty for believing in the distinct creation of a score of successive species of crocodiles in the course of countless ages of time. Science gives no countenance to such a wild fancy; nor can even the perverse ingenuity of a commentator pretend to discover this sense, in the simple words in which the writer of Genesis records the proceedings of the fifth and sixth days of the Creation.[35]

In this quotation and further on in the article, Huxley argues that any scientific hypothesis will outrun religious explanations of the origin of nature. Thereby, even the religious narrative will in turn be outrun by the style and storylines of scientific proofs. Huxley employs Darwin's evolutionary narrative and view of the world to get his audience to participate in telling and uncovering yet another evolutionary tale and thereby creating more authority. And he does it by repeatedly taking his audience's level of knowledge into consideration.

Scientists were aware of the fact that they belonged to a unified scientific community, where they, despite differences of opinion, still shared views of the progress in science. Scientists wrote their texts with their scientific worldview as background. Huxley was able to use the storyline that Darwin had established whilst Darwin, himself, made it clear that the scientist was the primary observer of nature, not God.[36] There can be no doubt that both Huxley and Darwin undertook the task to showcase the evolutionary storyline through their works, and with Huxley's article he clearly assumed that his audience was well aware that he was writing within the most obviously true storyline.

[31] Cf. Beer 2000 and Levine 1991.
[32] Darwin 1998, p. 5.
[33] Levine 1991, p. 1.
[34] Huxley 1909, p. 49.
[35] Huxley 1909, p. 49.
[36] Beer 1996, p. 383.

Figure 3.3: In the years after the publication of Darwin's *Origin and especially — as in this case — after his death (1882),* Darwin *was the subject of many satirical depictions. In this one, entitled "Man Is But A Worm",* Darwin *is situated in the midst of the chaos that is evolution. Often* Darwin *was seen depicted with apes even though he never claimed that humans descended from apes (or worms for that matter), only that humans shared a common ancestor with other primates (Source: Wikimedia).*

Contextualised Science

In the first section of the chapter, I have outlined some aspects of the role of the scientist in connection with scientific writings. Although the contextual level of scientific writings has not attracted as much attention as elements of the textual and linguistic levels from writers within the field of literature and science, a few major points are worth taking into consideration. There are, essentially, two main views when it comes to the contextual level: On the whole, historians of science in the field of literature and science have concentrated on the biographical lives of scientists in relation to their scientific writings.

On the one hand, literary critics have concentrated on the shared epistemology of science and literature in relation to the individual scientist or scientific text. According to literary writers like Levine and Beer, the main argument is that a scientist like Darwin took control, as it were, of his contemporary context. As Beer writes, Darwin recast "inherited mythologies, discourses, and narrative orders".[37] It is thus implied that Darwin used his theories to refer to a general cultural context and also to create a new referential context. In this respect, the scientist is very conscious of his use of textual elements (as we shall look further into below), and how he conveyed a particular worldview to his readers.

[37] Beer 2000, p. 3.

The position of the literary critics concerning the contextual level poses many interesting insights. Given that nineteenth-century literary writers and scientists wrote within a context with a shared particular epistemology, encompassing elements of both scientific and literary methods, we have a productive context from which the scientists themselves could frame scientific texts. Also, it seems likely that scientists were aware that they had to communicate their science to the public, which gave rise to new forms and styles of scientific texts. To have a present and attentive voice in a popular scientific text would help establish contact with the readers, as exemplified above with HUXLEY's article. Simultaneously, it would also be a way of maintaining authority, because the author (or narrator) could change between the role of the knowledgeable scientist and that of the readers' collaborator, for instance pointing out uncertainties of the theories. This authority, which the scientist can exercise in his writing, makes him capable of better communicate to his audience that his scientific theories fit his worldview flawlessly.[38]

Here we might return to two of the four problems, which BEER laid out in connection with DARWIN's *Origin*, namely that DARWIN was addressing a general readership and writing on the basis of an inherited discourse of natural history. According to writers like BEER and LEVINE, DARWIN solved these difficulties by presenting his audience with a particular storyline conveyed by a narrator, which both included and excluded the readers. For historians of science representing the opposing views in the field of literature and science, it might be argued that for instance DARWIN was writing in a context which he had no influence on, and that the development of his theories was as much an unconscious endeavour as a deliberate fabrication. It all comes down to considering the context of a scientific text primarily as an influence or seeing the scientific text as being an influence on the contemporary context. Regardless of the position concerning the contextual level in connection with scientific writings, the aspects of the shared epistemology, conveying a particular worldview and understanding of the audience have an influence on the textual level, which will be the subject of the next section.

3.3 The Textual Level

Dealing with scientific literature and other non-fictional works, one might allocate these types of texts into one or more of the following categories: descriptive, narrative, interpreting, argumentative or instructive.[39] Scientific texts in the late nineteenth century would often be argumentative and narrative, as is also the case with HUXLEY's article and DARWIN's works. In addition to the overall categories, there are also different traditions of viewing the way in which the texts are constructed and what the order of the storyline is: Cause and effect, inductive and deductive argumentation, chronological or composed

[38] Shuttleworth and Cantor 2004, pp. 1–3.
[39] Jørgensen 1999, pp. 147–149.

with a typical narrative structure, where the text will mount into a climax and move to an anticlimax with falling intensity.[40]

In this section, the aim is to look more closely at the various elements that can constitute the textual level of the scientific texts. It has already been established that scientists in the Victorian period were influenced by literature, but to look at the concrete components of the scientific texts in contrast to literary elements is a different matter. Thus, we now go from the context and the intentions of the scientists to focus more closely on the texts themselves. In order to get a full view of the literary elements in the structures of the scientific texts, the following components will be investigated in relation to Darwin and Huxley's works: The storyline in the texts, the style of the texts, the narrator in the scientific texts and lastly the usage of 'characters' in the texts.

Concerning the narrator, he has always played an important part in literary criticism and textual analysis, but the narrator is rarely considered when it comes to scientific texts. However, I will argue in the following that the scientific author in certain circumstances can employ a narrator character or himself take up the role as narrator. In the scientific texts the role of the narrator is important, I will argue, since it is in the text that the scientist has to create authority and an objective voice.[41] This section of the chapter consequently deals with the questions of how and with which effects the storylines are outlined in the scientific texts, and whether the style of the scientific text generates certain views. And finally, I want to deal with the question of how a narrator and characters in scientific texts play a central role in relation to the overall argumentations of the text.

The elements of this section also refer back to what has been discussed in the previous section of this chapter. Indeed, there are close connections between how the scientists chose to convey a particular worldview and use a narrator and how scientists used a particular style, created characters and had storylines in their texts. Again taking Darwin as the primary example, Beer takes a deconstructionist approach, arguing that *Origin* and other of Darwin's works do not relate to the 'real world'. She argues that the elements (objects, animals, plants, etc.), which Darwin describes, function as characters in a novel and that all objects described are merely linguistic signs that do not have physical references outside the text.[42]

Many historians of science writing on literature and science dispute this; Gross does not see Darwin's language (and scientific texts in general) as devoid of any reference in nature. Gross agrees that facts are basically a linguistic construction and that there would be no facts without a language to communicate them through, but these facts although linguistic are not without reference to the world outside the text and language.

[40] Jørgensen 1999, pp. 143–145, 147–149.

[41] One can argue that the role of the narrator could be discussed in relation to the contextual level of this dissertation, because the narrator in many ways is similar to the author. However, I will argue that the narrator fundamentally is a construction that exists only within the textual frame.

[42] Beer 1986, p. 220; Beer 2000, p. 39.

But in Gross' perspective, the scientific texts in every detail refer to the world outside the texts.[43]

Instead, Gross deals with how Darwin's rhetoric is evolutionary and thus in some ways mimics his theories.[44] According to Gross, Darwin's evolutionary rhetoric is not just another way of classifying nature on the basis of a specific construction. The evolutionary rhetoric and theory help evolution by being able to predict and not only describe development in nature.[45] Thus, he sees Darwin's language as active and almost capable of scientific explorations in itself, whereas the deconstructionist approach has the Darwinist language passively stuck in a self-referential world.

These views represented by Gross and Beer, respectively, are once again characteristic of the opposing views on science and scientific texts as discussed above. Both Beer and Gross' views are valid and can be used to give new insights into Darwin's works. However, as suggested previously, the Darwin-case may well be the perfect case for both sides of the field of literature and science. Therefore, when looking at other cases, for example the case of thermodynamics in Chapter Four, one may have to favour one view over the other, because the Darwin-case has to a great extent set the standards for how the relations between science and literature in the nineteenth century were analysed. Therefore, despite the fundamental differences on the nature of science, both Beer and Gross' view can be used in relation to the Darwin-case with equal strength.

The Storylines in Scientific Writings

Throughout the nineteenth century, science not only had to piece together an extraordinary amount of new scientific evidence and knowledge in order to form a new story of nature, but science also had to confront the religious world view still predominant at the time. Scientific facts and the scientific narratives were gradually replacing the Bible as the only source of the true interpretation of the world. As mentioned in Chapter One, by the mid-nineteenth century science had built up a style of objectiveness and authority from which its theories could be communicated. Science as a whole was (and still is) connected to advancement, because science and scientific work are linked to progress of knowledge and new conquests. However, progress was also linked to many different theories of the time claiming that life had evolved; the Earth had changed significantly, and so on.[46]

Hence, progress and growth were fundamental parts of the public's view of science as it was also amongst scientists themselves. Scientists utilised this notion of progress in their writings in order to make clear what science stood for when opposed to religion or past scientific theories, which were not seen as progressive. Scientists had to convince

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[43] Gross 1990, p. 203.

[44] One of the central discussions on Darwin's works concerns whether Darwin's rhetoric, style and intentions primarily are evolutionary or revolutionary. In his *Science as Writing*, Locke argues that Darwin's rhetoric is revolutionary (Locke 1992; see below).

[45] Gross 1990, pp. 33–39.

[46] Beer 1990, p. 82.

people that humans and animals had evolved — and though this may be seen as a scientific version of Genesis, it was still an unbelievable thought to most people and it became important to present a chronological storyline that could help convince the reader.[47,48] Huxley's article on chalk is an example of a predominantly chronological storyline. He presents his readers with the origins and dissemination of chalk. In the same way as Eliot uses the town of Middlemarch as representative of the entire world, Huxley also uses his single piece of chalk to represent all chalk in the rest of the world. Thus, scientists used their scientific writing to make believable the different scenarios that the various scientific theories proposed. It was important to make clear the concrete matters of fact because these matters of facts were the basis of creating a story, in which a central theory could become authoritative and get the general public to believe in these — often — unbelievable theories.

Again, Darwin's *Origin* may serve as a fine example of how storylines were used and developed in the scientific writings during the Victorian age. Darwin starts his narrative *in medias res*, though the title of the book suggests that he writes about the origins of species. However, the full title of *Origin* is *On the Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, and taking that into account, it is clear that Darwin does not intend to write on origin as such, but on a specific kind of origin.[49] In Darwin's work, there are a number of different storylines or plots. Beer, discussing Darwin's plots, points out that Charles Lyell and Darwin proved it possible to create major narratives of geological and natural history in their storylines. Indeed, Darwin produces a storyline interconnecting all the species in the world.[50]

However, the main storyline of course has to do with evolution itself. Darwin believes in gradualism (as opposed to catastrophism), basically claiming that nature does not take leaps. Levine argues that in order for Darwin's story to start properly, it would demand a quite catastrophic event so that nothing could become something and inorganic could become organic. Despite the abrupt start of Darwin's evolutionary storyline the ending of the evolutionary narrative also is different from previous narratives. With the narrative of natural theology, the ending of the story is already known; that is, there is a telos in nature with the human race having an elevated position. On the other hand, the evolutionary storyline can only be closed 'artificially' because there is no ultimate point of evolution: Everything is still evolving and therefore Darwin also had to close his storyline with an open ending.[51]

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[47] Otis 2002, pp. 11–12.

[48] In their book *Reconstructing Nature* (Brooke and Cantor 2000), Brooke and Cantor argue for a new way of looking at the master narrative that has been told about science and religion. Through a series of case studies from the history of science, Brooke and Cantor show how religion often has been inspired by scientific ideas and likewise how religion incorporated religious ideas. They also make clear how the religious ideas have an influence on science in the nineteenth century, although they do not deal with these influences on a textual level.

[49] Beer 2000, pp. 58–59.

[50] Beer 1986, p. 222; Beer 2000, p. 17.

[51] Levine 1991, pp. 47, 96.

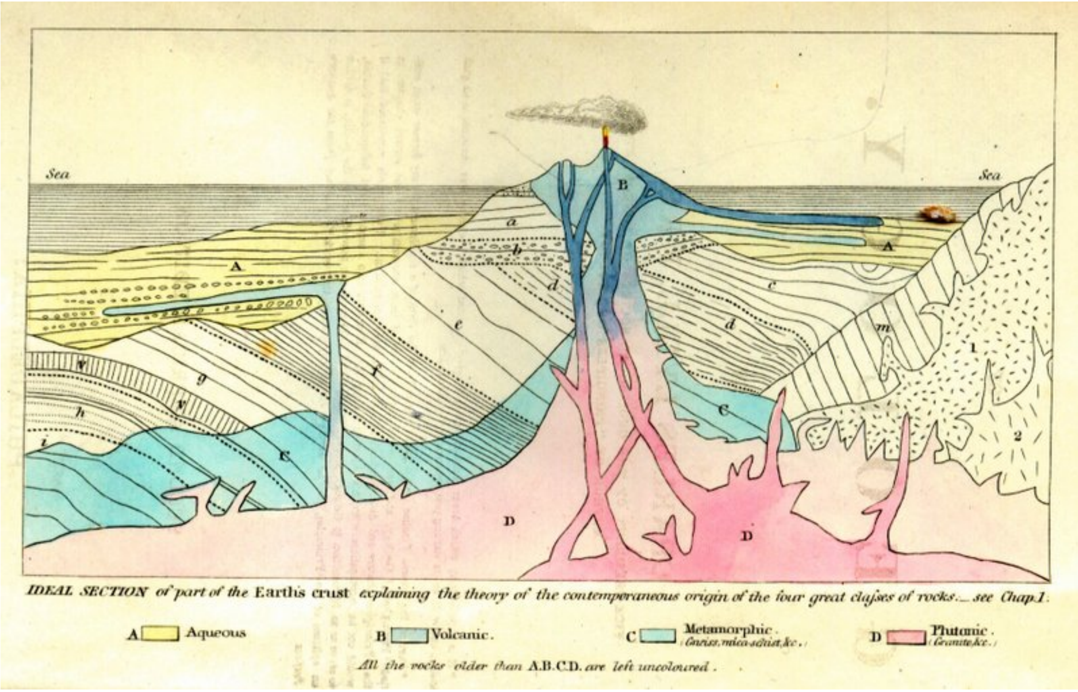

Figure 3.4: The frontispiece from the second edition of CHARLES LYELL'S *Principles of Geology (1857), showing the origins of different rock types beneath the earth — an illustration that helped prove his theory of the age of the Earth. (Source: Wikimedia).*

The many storylines in *Origin* are complex and interwoven, something which is also characteristic of the characters of the novels of the Victorian period. Dealing with large timescales, individual species, the place of the human race in evolution, etc., DARWIN produces a multi-plot structure in his book that is testing his readers' ability to comprehend his storylines. At the same time, it appears strong and convincing because the plots take many different aspects of life and nature into account. BEER points out the use of *fabula* and *sujet* in *Origin*, where fabula represents the time periods he tells of and sujet deals with the materials (for instance species or natural selection), which are exclusive for his specific theory. In this respect, one might turn to a famous metaphor in *Origin*, which is the 'entangled bank'[52], where DARWIN describes all species as complex interconnections which very well depict not only evolution but also his own storylines.[53]

In the end, the two sides of the field of literature and science bring out the different views on the use of storyline in scientific texts. To the literary critics, the storyline is constructed 'literarily' whereas the historians of science argue that storylines in scientific texts are constructed on the basis of nature. Again we see that both analyses of the

[52]In the concluding chapter of *Origin*, DARWIN uses the metaphor of the entangled bank to describe the complexity of nature. He writes: "It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us" (Darwin 1998, p. 395).

[53]Beer 2000, p. 39; Levine 1991, pp. 18–20.

storylines fit the Darwin-case very well, but may not fit universally to other scientific texts.

The Style of the Scientific Writings

Studying nineteenth-century scientific writings involves storylines, audience, genre of text, language, etc., but in this section I will take a look at the 'evolutionary style' of scientific writing represented by Darwin and Huxley. As Shapin argues, the objectivity displayed (or desired to be displayed) through the scientific writings was to a certain extent only a stylistic and linguistic construction.[54] Not many of the literary critics in the field of literature and science would disagree with Shapin's notion of style, and they will even go further in their deconstructions of the scientific texts. Levine writes on Darwin's style in *Origin* that the book:

> [B]egins with Darwin describing how he was 'struck' by a point and then 'driven to conclude'. The location is no accident but a stylistic choice representative of Darwin's scientific method, a method that entails the irrelevance of personal choice. Darwin is not responsible for the murder; nature is.[55]

The style of Darwin's text is thus a deliberate fabrication interconnected with the theories he communicates. That his style is still seen as authoritative and objective results from his usage of key words like the word 'fact'. In the Victorian age the word fact denoted authority and objectivity, as it still does today. But when Darwin uses the word he rather alludes to familiarity between the species than to evolution as such, Beer argues. Hence, Darwin does not claim that evolution is a fact, but there are a number of other facts in nature that in the end may lead us (both Darwin and the reader) to believe that evolution is a fact.[56]

Regardless of Darwin's use (or misuse) of the word fact, he already on the first page writes that *Origin* is only a provisionally abstract of his final thesis. He therefore points out that the book may be filled with errors and that there is no empirical basis for many of the claims in the book, much the same way as Huxley points out weaknesses of his own argumentation in his article on chalk.[57] Despite the fact that Darwin already proclaims from the beginning that he has no evidence of his claims, the book was still convincing to many of the readers and was seen as objective and scientific.[58] In Beer and Levine's perspective this is due to the circumstance that Darwin's style of writing in some ways mimics his theories, becoming an evolutionary rhetoric. The reader is forced to use his imagination, because otherwise evolutionary theory would be too difficult to believe in, and therefore the reader is helped along with an imaginative language-use.[59]

[54] See Chapter Two, p. 32; Shapin 1984.
[55] Levine 1993, p. 385.
[56] Beer 2000, p. 75.
[57] Huxley 1909, p. 31.
[58] Darwin 1998, p. 4.
[59] Beer 2000, p. 75.

The counter-argument against Levine and Beer's views on style can, once again, be found in Gross. Gross writes that in every scientific text, the rhetoric and style will inadvertently be filled with elements of the rhetorical logos, ethos and pathos simply because it is a fundamental part of being human and possessing a language.[60] Gross' take on style is, as we have seen before, not influenced by the same constructivism, and therefore he is more likely to view Darwin's style as a 'personal' style, rather than a style solely dictated by his theories. Turning our attention to pathos, the rhetorical mode of persuasion appealing to the emotions of the audience, which is apparent in *Origin*, several writers have commented on Darwin's use of anthropomorphisms and personified nature. The literary critic David Locke, who has written on Darwin's use of pathos, uses the example of the slave ant that refers to the stereotypical Victorian domestic servant, who must struggle not to be the victim of his masters (i.e. other ants). Unfortunately for Darwin's slave ant, it gets killed in the end. The pathos in the story of the slave ant is evident, according to Locke, and points to the fact that Darwin himself was a witness to how ants behave in the natural world.[61]

Huxley's article also leans towards Darwin's evolutionary style and overall storyline, as mentioned above. If we take a closer look at some of the devises that constitute Huxley's style, we first encounter many references to history in general. Huxley refers repeatedly to English history, geography and language, and even points out that the alternate name for England, Albion, derives from the Latin word for chalk. In addition, he makes sure to point out that the local conditions in England mime the rest of the world, so the local becomes global. By using the local and national, Huxley is also able to create images that his readers can more easily relate to; like Darwin's ants.

Like Darwin, Huxley does not, as mentioned, make use of empirical proofs, which he also states at the beginning of the article,[62] and like in the case of *Origin* Huxley gives no promise of an undisputable truth. Another interesting point about Huxley's style is his use of imagery that the readers can relate to, since he usually starts out on a large scale, for instance the chalk we find in nature, and brings the readers down under the microscope with him. From here on it becomes unfamiliar and more scientific. Another example is when he uses everyday examples to illustrate the basic components of chalk: "[T]he fur on the inside of a tea-kettle is carbonate of lime; and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below".[63] In both cases, Huxley takes a familiar picture and transforms it into something else, and like Darwin, he can be said to illustrate his points on evolution with a particular style of mirroring certain rhetorical figures.

For both Huxley and Darwin, their storylines and general style in their texts helped communicate their theories through the texts' narrative structures and rhetoric. The par-

[60] Gross 1990, p. 16.
[61] Locke 1992, pp. 76–79.
[62] See Chapter One, p. 7.
[63] Huxley 1909, p. 32.

ticular evolutionary style consists first of all of various key words and metaphors, which will be further dealt with in the final section of this chapter. Furthermore, the evolutionary style shows evolution at work in the language and storyline: Darwin and Huxley's storylines evolve from certain observations of nature to become a complete story of evolution. This view of the style and storyline of the evolutionary theorists is more likely to be accepted by the literary scholars of the field of literature and science than by the historians of science, who rather would argue that the style of the evolutionary scientists of the period only points towards their own personal linguistic and literary abilities or imagination.

The Voice of the Narrator

The figure of the narrator is most often linked to works of fiction and rarely to scientific texts. Additionally, the narrator rarely, if ever, plays a role in the historiography of science; scientific texts are seen to *show* or *represent* rather than *tell* or *narrate*. When scientists in the nineteenth century tried to convey a particular worldview in a particular scientific context, there arose a demand for some kind of narrator, especially in popular science writings. If a scientist only wanted to present his findings or certain calculations without further argumentations, then the narrator would not be necessary. But for instance in popular science, I will suggest below, the narrator will have a certain role to play. One might thus reasonably ask what role does the voice of the narrator play in these texts in contrast to the scientist author? And with what authority does the narrator speak in relation to the author? The narrator of the scientific text would have the same scientific views as the author and will not present an unreliable version of nature, which might crop up in a novel. But at the same time, the narrator will be distinct from the author in the scientific texts.

Hence, we might assume that the narrator has a role in the popular science writings and the role of the narrator is not unlike the role of the narrator in literature and vice versa. As Levine writes on the traditional scientist narrator of Victorian fiction:

> The narrators themselves are preoccupied with authenticating their positions, testing their own ability to withstand the mists of bias, storms of emotion, and finding strategies by which to overcome the limits of consciousness. Plots emphasize the traditional narrative concern with what happens next by concentrating on the search to discover what has already happened, making that concern their subject and suggesting that close observation would provide information for resolving narrative complications.[64]

Levine's characterisation of the narrators in Victorian fiction fits well with the types of narrators found in the scientific writings of the time. If we take Huxley's article as an example, his narrator is set to authenticate the position of evolutionary theory and all that follows. Likewise, Darwin showed how the narrator when communicating about humans

[64]Levine 1991, p. 221.

must be disinterested and observant and thereby be in control of the emotions, biases, etc. that automatically would occur. In addition, Huxley's narrator guides his reader through the past in order to figure out the structures of today and how evolution may further alter, in this case, the distribution and nature of chalk.

Assuming that the narrator upholds the same authority as the scientist author, the reader will not automatically question the reliability of the narrator. Levine writes on the Victorian novel:

> The omniscient author convention — with its apparently unself-conscious directness of representation — does not inevitably treat the novelist's and narrator's activity of observation as unproblematic, and even when it seems to, it raises the problems of observation by filling narratives with unreliable spectators [...] The trick, as Darwin's own self-effacing strategies attest, is to avoid the exposure and thus the vulnerability that the act of observing normally if ironically entails.[65]

Consequently, there will always be some form of unreliability when it comes to the narrator in scientific texts. In the case of Darwin, the narrator as observer is also part of the observed and, though more knowledgeable on the subject, will be in the same situation as the reader. In the case of Huxley, the unreliability furthermore lies in the fact that the narrator willingly invites the reader to discover alongside with him. In the end only the narrator will be able to lay out the story of chalk as he desires. And because the reader in this particular story is asked to follow the narrator's moves in order to discover the true story, it becomes difficult for the reader to judge the information put to him by the narrator.

It is the narrator who will argue to the reader how and why a particular subject-matter is important and not just deliver self-evident scientific facts: The scientist will already have chosen the subject, and the narrator's role is to create a story within the subject outlined. Thus, the authority with which the narrator speaks is on the whole the same as that of the scientists who wrote the piece. Besides, the narrator is able to make certain choices on behalf of his audience. Huxley for instance writes at some point that it is unnecessary to write more about a certain type of deep-sea creature, and thereby as a narrator makes an authoritarian decision about which information should be conveyed to the readers.[66] In addition, the role of the science narrator, as it is also the case of Huxley, has more to do with convincing the audience than telling or instructing the audience. The authority of the narrator in scientific texts is in some ways the same as that of the narrator in fictional works; the subject itself cannot be tampered with, but how a subject-matter is conveyed and how the reader sees it is very much linked to the narrator.

In Victorian fiction, the narrator had a new role: "Victorian novelists increasingly seek a role for themselves within the language of the text as observer or experimenter, rather than as designer or god. Omniscience goes, omnipotence is concealed", as Beer

[65] Levine 1991, p. 15.

[66] Huxley 1909, pp. 36–37.

writes.[67] The narrator in Victorian fiction was said to uphold methods of science, or rather the narrator in fictional works functioned like a scientist. Beer writes in *Darwin's Plots*:

> Lyell, and later Darwin, demonstrated in their major narratives of geological and natural history that it was possible to have plot without man — both plot previous to man and plot even now regardless of him [...] The living world is neither entirely open to man's observation nor related to him.[68]

A new way of describing, viewing and fictionalising the world was thus introduced. The shift in the narratives in science also meant that it was no longer possible to interpret nature as it pleased the author. But even though science in this quotation is said to inspire literature (and not the other way round) it is still important to see how the role of the scientist as an observer and experimenter inadvertently came into being in the period.

The scientist as author established authority before his readers, otherwise the aim of science in general would be pointless and science would lose its authority and objective voice. However, this objectivity and authority would be attributed to the narrator role in the scientific texts: The scientific text is seen as objective whether being a professional science text or a popular science text. The 'objective' and observant narrator in the scientific text becomes very similar to the narrator seen in naturalistic and realistic fictional works in the period. Consequently, one can say that literary authors used the scientist as a role model for their narrator, but at the same time the popular science writings also used a narrator as used in fiction, as means of convincing the audience rather than actually proving a theory. Once again, we see the mutual inspiration and the shared epistemology between fiction and science in the period.

To exemplify this role of the narrator of fictional works as an omniscient narrator that guides the reader through the story, we might once again turn to Eliot's *Middlemarch*. *Middlemarch* is a work that incorporates many scientific aspects, something that also has an influence on its narrator. In Eliot's work, the reader encounters a narrator characterised by objectiveness and authority and interferes with her characters. The novel starts out with the narrator setting the scenes for the following detailed descriptions of the people of Middlemarch. Thus, the narrator from the beginning intrudes in the story in much the same way as a scientist would when performing an experiment. Eliot's narrator, who is represented in the text in the first person tense comments on the events in Middlemarch but cannot, and will not, interfere with her characters' lives. She sees her characters in a very scientific way; or rather she writes in the context of the shared scientific and literary epistemology of the time, as Levine would put it.[69] One can view Eliot's way of presenting her story as a parallel to that of Huxley in his article on chalk. As it is the case in *Middlemarch*, Huxley's narrator starts out with some very general and universal observations: Eliot's narrator talks of Saint Theresa, a metaphor for the main

[67] Beer 2000, p. 40.
[68] Beer 2000, p. 17.
[69] See Chapter Three, p. 45.

character Dorothea Brooke, whereas Huxley's narrator establishes that chalk is found in every part of nature all around the world.

As was the case with Eliot, Huxley likewise does not present the readers with an all-knowing godlike narrator. In Huxley's article it is clear from the beginning that it is the chalk itself that tells a story and the role of the narrator is to make the reader see how the chalk influences our history and lives in general. Before introducing their main characters and their environment, Huxley and Eliot establish the role of the narrator: Both narrators will lay out a particular line of argumentation or story for the readers to follow, as Huxley writes: "[I]n truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest".[70] And Eliot writes in her prelude: "Who that cares much to know the history of man, and how the mysterious mixture behaves under the varying experiments of Time, has not dwelt, at least briefly, in the life of Saint Theresa".[71] Thus, both Huxley and Eliot's narrators are not there to answer any questions, but to exemplify to the audience.

In *Middlemarch* the narrator sees everything, but is reluctant and will only occasionally give her comments on the events of the story. This commentating 'I' will usually convey certain feelings and opinions about certain characters or certain aspects in the story. For instance, Eliot's narrator typically states "poor Lydgate"[72] when this main character has worries or is in trouble. The narrator in this respect does not have the power to alter the plot, characters or matters of facts, but she has got the authority to put them into a specific context and convey certain opinions on the characters.

Likewise, Huxley cannot alter the evolutionary plot, but he chooses his (and thereby also the reader's) focus points of the piece of chalk. In this respect, the popular science text differs from more hard-core scientific writings: The narrator is present in the popular science texts as a guide for the reader, but the role of the narrator is also to make sure that the particular worldview of the scientist will be brought forward. In this respect, certain views are conveyed, which in the end is not what one might expect from a scientific text. But, as we have seen, neither Darwin nor Huxley set out primarily to communicate empirical facts in their writings.

The Narrators of Evolutionary Tales

Turning the attention to the narrator in Darwin's *Origin*, it is once again critics like Levine and Beer, who have taken an interest in how Darwin's narrator is different from the author Darwin. Realising that Darwin's primary audience, according to himself at least, was the 'educated reader', it is not surprising that Darwin in his work is aware of his audience's frame of reflection and knowledge. In several of his books and articles on Darwin, Levine

[70]Huxley 1909, p. 31.
[71]Eliot 1965, p. 25.
[72]See, for example, Eliot 1965, p. 78.

has written about the type of scientist that DARWIN stands for and portrays in his works. DARWIN's ideal scientist is the observer scientist who has a certain distance to his subject — what LEVINE calls the disinterested observer. According to LEVINE, DARWIN's type of scientist demonstrates how science could look at the human race as just another species in nature.[73] The fact was that the narrator's task was concerned with communicating the human race's place in nature to an audience of humans whilst being a human himself.[74]

In HUXLEY's article the pronoun 'we' is used repeatedly and signifies two different groups: the 'we' that is the author, narrator and the readers, and the 'we' that is the writer and the rest of the scientific community. When referring to the scientific community, the narrator will often describe the scientific background of a particular statement. HUXLEY thus refers to most of the scientific theories and experiments that have resulted in certain assumptions concerning evolutionary theory. HUXLEY talks of scientific theories as a background for his story of chalk, but he keeps it in a light and noticeably non-scientific language, although he also uses 'we' about himself and the scientific community. He writes for instance:

> Dr. Wallich[75] verified my observation, and added the interesting discovery, that, not unfrequently, bodies similar to these 'coccoliths' were aggregated together [. . .] So far as we knew, these bodies, the nature of which is extremely puzzling and problematic, were peculiar to the Atlantic soundings.[76]

In this quotation, HUXLEY makes it clear that he is a part of the contemporary scientific community, and has an important role to play both as a scientist and as a communicator of science. When on the other hand, HUXLEY refers to himself and his readers as 'we', differences are noticeable. HUXLEY writes: "The language of the chalk is not hard to learn, [. . .] if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell out that story together".[77] Here, the narrator does not assume the kind of scientific authority, which might tell the audience that there is further information on the topic, which they do not need to know. Hence, HUXLEY's narrator is on a 'quest' on equal terms with his readers. The narrator therefore has two different roles in the text and both be on the readers' and the scientific community's side.

DARWIN's narrator also makes use of the first person plural when addressing the reader. But unlike HUXLEY, DARWIN first and foremost uses 'we' when speaking in general terms, for instance in phrases like 'If we look to', and in this case DARWIN is not addressing the audience, but demonstrating the nature of the disinterested observer, as LEVINE characterises it. This 'we' confirms that the narrator has an objective stance to his subject, which in the end also includes the audience.[78] But DARWIN's narrator also uses

[73] ELIOT's narrator in *Middlemarch* displays the same notion of disinterested observer, when she sets about investigating the human race in the town of Middlemarch in the prologue.

[74] Levine 1991, pp. 212–213; Levine 1993, pp. 372–373.

[75] (1786–1854). Contemporary botanist and surgeon.

[76] Huxley 1909, pp. 38–39.

[77] Huxley 1909, p. 32.

[78] Levine 1991, p. 214.

a 'we' that does include rather than exclude his audience. Beer points out how Darwin includes his audience at certain times in *Origin*. For instance, she has found that often when speaking of how humans are closely allied with other species or how individuality and community function in the natural world, Darwin often uses the including 'we' form. Thus, the reader is "drawn into a relationship which appears socially reliable with the personae generated by the discourse of the text", Beer argues.[79] Thereby, the narrator includes the reader in reality presented by the work and functions, as it is also the case of Huxley, as a guide or companion, who helps the audience to interpret the observations stated in the work.[80]

Scientific Characters

Can one rightly claim that there are characters in scientific texts in the same way, as we understand characters in works of fiction? And if so, how are these characters constituted in the scientific texts? If we look at scientific texts as character novels I will argue in some cases that we can. Parallel to the classic character novel of the Victorian period, scientific texts often presented theories by introducing various minor elements (or characters) in order to better explain how the theories work and to relate them to a whole theory complex, as seen with Huxley's article above. When it comes to scientific writings in the Victorian period, a specific scientific theory or main argument may function as a protagonist or character in a text. Likewise, the individual elements in the composition of a text will always be able to assist the reader in his search for the meaning of the text and indeed of the scientific theory.

One of the first scientists presenting his subject matter using something reminding of characters was Lyell. In his *The Principles of Geology*, Lyell deals with a large time-scale of geological history, in which he interprets different geological layers. Beer writes on and quotes Lyell: "The 'characters' are physical objects: rocks, animals, and plants. The systematisation and comparison between 'distant eras' brings an 'acknowledgement, as it were, that parts at least of the ancient memorials of nature were written in a living language'".[81] The world of geology, which Lyell presents, has signs and characters that function as a form of language that can be read. Beer also presents the same argument for Darwin's work (see above), and there can be no doubt that Darwin, Huxley and other disciples of evolution were greatly inspired by Lyell. There is, of course, a double meaning of the word character meaning both forms of signs and a form of personae. To get to grips with the use of characters we may look upon Darwin and Huxley's writings once again in order to explore how they in their works made use of characters, as they would be used in for instance a novel.

[79] Beer 1986, p. 225.
[80] Beer 1986, pp. 223–225.
[81] Beer 2000, p. 39.

There are, of course, fundamental differences between how literary writers use characters in their fiction and how scientists use characters in scientific writings. However, if we view key concepts and elements in science as characters, they exhibit similarities to fictional characters: Like fictional characters, scientific phenomena or entities often do not in actual fact exist: For instance, the concept of force, which then and now is accepted as 'something', but which cannot as such be measured or observed. The different characters moreover have some representative and recognisable features, which the reader will know or come to know as he reads the work.[82,83]

The way in which LYELL used concrete physical objects as characters is also apparent in HUXLEY's examination of chalk. HUXLEY's small piece of chalk is an obvious protagonist in his article. In the beginning of his article, HUXLEY's piece of chalk is introduced as a familiar part of the local scenery with certain attributes: "[W]hite substance almost too soft to be called rock".[84] After placing the chalk in time and space the chalk's story tells about evolution. HUXLEY wants to let the chalk "tell us its own history", as he writes.[85] Thereby, HUXLEY makes it clear that the chalk is a character in its own right that is able to assist HUXLEY in explaining his theory. The choice of a piece of chalk as a protagonist meant that HUXLEY was able to illustrate his basic scientific views on evolution through a familiar thing that also has cultural and historical significance for his audience. Also, HUXLEY's chalk ends up almost having a life, and indeed evolutionary story, of its own composed by different scientific elements and facts as well as different historical references. Hence, HUXLEY's chalk becomes a specific chalk with its own story and points of references, created and upheld by the features chosen by HUXLEY. In this way, HUXLEY's piece of chalk only represents chalk that exists in the real world, more than it belongs to the chalk 'out there'. In this way, HUXLEY's presentation of his main character resembles what we might find in a fictional work such as ELIOT's *Middlemarch*. In the prologue, ELIOT's main character Dorothea Brooks is characterised as St. Theresa. Hereby ELIOT, like HUXLEY, establishes the basic features of her main character.

Also in the case of DARWIN and *Origin*, examples of the use of characters are plenty. It has already been discussed how DARWIN's animals, plants, etc., were anthropomorphisms (see above), which naturally can be seen as forms of characters. However, his different species play only minor roles in the overall story. Several critics have taken an interest in the different characters in DARWIN's works, amongst those LEVINE, who has investigated DARWIN's two main characters — a male and a female, respectively. It is not uncommon that nature is referred to as 'she'; this has been seen for many centuries in scientific as well as non-scientific writings.[86] Therefore, it is not surprising that DARWIN uses the personal pronoun 'she' about nature, although the nature in *Origin* is different from nature

[82] In science, however, certain features of a phenomenon may change; for instance, the concept of energy has changed considerably over the last couple of centuries.

[83] Gross 1990, pp. 7–8.

[84] Huxley 1909, p. 30.

[85] Huxley 1909, p. 33.

[86] Beer 1986, pp. 230–234.

in other scientific writings. The primary and strongest characteristic of DARWIN's nature is that she selects, or rather she *is* natural selection. DARWIN's nature thus implies a form of activity or agent as opposed to a passive nature. DARWIN does not claim, however, that his nature consciously, as it were, selects or favours one species in preference of another. Nonetheless, DARWIN's nature plays the main role throughout the book and is also one of the more controversial elements in his work, because previously this role was reserved for a divine being which would be the prime selector in nature.[87,88]

The other main character that LEVINE focuses on is not an apparently present character, but a character that nonetheless has a significant meaning in *Origin*. DARWIN toys with the thought of how evolution will manifest itself in several thousands of years. He professes a supreme being, a 'he', which will have evolved considerably from the human race, as we know it. Even though DARWIN only briefly mentions this supreme being it lies as an underlying notion throughout the book that this is the consequent and main argument of DARWIN's work: The human race has evolved and will continue to do so.[89] Thus, DARWIN's two main characters represent his two main arguments in *Origin*. The reader follows both characters and their development, which of course also refers to the general theme of evolution. The characters in this form of 'evolutionary narratives' thus get a chance to evolve through the texts like metaphors, sometimes controllable sometimes not (see below) and help give new meanings to the text. Hence, the characters of DARWIN's writings on evolution are not static but part of an evolution.

The Topical Centres of the Text

Throughout this section of this chapter, I have dealt with the topical level of the scientific text: How the themes and theories of the texts have been presented by the means of literary elements of a particular argumentation, style and storyline as well as the use of different characters and a narrator in the scientific text. It is clear that central to most scientific texts is the presence of certain theoretical terms and keywords, which may also be equal to characters. Thus, like fictional authors of the Victorian period HUXLEY, DARWIN and other scientists could use their characters and storylines to produce texts that would draw the reader into another world, where, interestingly enough, scientific facts were not the most important feature. Instead, it was important for the reader to be able to follow a character's development and a particular storyline in a believable framework under the guidance of the narrator.

Let us briefly return to one of BEER's four problems that DARWIN encountered when writing *Origin*: The fact that language includes agency result in a text where someone or something has to act. As we have seen in both the cases of HUXLEY and DARWIN there is a fundamental discussion on who or what actually acts in the text: Is it the main characters

[87] Levine 1993, pp. 386–387.

[88] Furthermore, other critics have argued that DARWIN's female version of Nature refers to a form of virginity which should be looked at and revealed in order to study and worship (see Beer 1986).

[89] Levine 1993, pp. 385–386.

or narrator who act in the text or is the style and the storyline fundamentally in control of what happens? As discussed in the previous section on the contextual level of the text, the fundamental disagreement amongst critics were whether it was the scientist and his story or the author of a text that was in charge of the language, narrator and communication of the scientific ideas or theories.

In this section the central discussion is somewhat the same: Does the storyline, style, narrator and characters mimic the theories consciously, or is it merely a stylistic feature that was present at the time of the writing and publication of the texts? Overall, the literary critics of the field of literature and science have taken a greater interest in details of aspects of the text. However, the overall main differences in the field of literature and science are still visible when looking into the textual features. As we move still deeper into the texts, the disparity between different critics within the field of literature and science will be even more apparent.

3.4 Language and Tropes in Scientific Writings

Numerous articles and works on the literary history of science have dealt with language and specific words used in scientific writings in relation to the topics of scientific ideas and theories. In this section, I will look into various tropes and their roles in the scientific texts. Moving more closely to the level of textual analysis I will concentrate on some of the types of tropes and figures[90] used specifically in Victorian science writings exemplified by Darwin and Huxley. Dealing with the specific language-use of scientific writings, it might be somewhat straightforward to link the topics of a particular scientific text with the use of tropes. This notion has been argued by among others the historian of science Ofer Gal, who states that although tropes and topics are mutually dependent on each other, they must be analysed separately because there are differences when it comes to the stability of meaning in the two elements:[91]

In his article on tropes and topics in scientific texts, Gal writes on the topical aspect that "the topical aspect tends to be more stable than the tropical and to remain unchanged while the latter is transmuted — sometimes quite radically — securing by its stability the continuation of communication in situations of paradigmatic changes".[92] In this quotation, Gal thus argues that tropes over time change meaning, whereas the overall topics of the scientific texts will be more stable. But although the topics of the texts are more stable, the tropes of the text, whether stable or not, play a significant role in the communication of the scientific writings. Gal's points on tropes and topics emerge clearly

[90]Traditionally in literary criticism, figures have to do with word order and often appeal to the emotions of the reader. Figures will only affect the expression and not the content, as it would be the case with tropes. Tropes (e.g. metaphors, metonomies, symbols, etc.) appeal to the intellect and are more radical when it comes to meaning changes (Jørgensen 1999, pp. 67–68). In the theoretical explanation I will mainly concentrate on tropes.

[91]Gal 1994, p. 34.

[92]Gal 1994, p. 37.

when considering the storylines, style and characters of the scientific texts: All of these aspects are exchangeable to some extent, but still the overall meaning of the scientific text will be the same.

In the following, I will concentrate on a number of selected features of the tropes and literary language-use that are noticeable in the scientific texts, since it would be impossible to give a full view of the different types of tropes in science and how they work. Therefore, I have chosen partly to focus on some general features of the tropes and language-use of the Victorian age and partly to focus on the tropes and language specific to the case of Darwin and evolutionary theory. Once again, the Darwin-case has set many of the standards for how the language and tropes in Victorian scientific writing are treated within the field of literature and science. Hence, the features that are included in this section of the chapter mostly deal with the tropes that are found in Darwin's work — metaphor, analogy, metonymy and allegory — whilst tropes like irony and hyperbole are not taken into consideration.

This section of the chapter will be composed of three main parts. Firstly, there will be a general overview of the scientific language with emphasis on the notion of imagination that was an essential part of Victorian science and science writing: To understand the nature of the tropes it is therefore essential to briefly deal with the scientists' creativity. Secondly, I will briefly elucidate some of the studies and theories on literary language-use in science. And thirdly, I will take a look at some of the most used literary tropes and constructions in science writings of Victorian science, namely metaphors and analogies and to a lesser extent metonymies and allegories. Each group of tropes plays a different role in science writing and has evolved and changed throughout the centuries. I will thus again concentrate on the scientific texts on evolutionary theory and the specific meanings of various tropes in those particular texts. In the following chapter, I will turn my emphasis to the tropes that are dominant in connection with thermodynamics and not evolutionary theory.

Understandings of the Language of Victorian Science

Although the usual notion of scientific language is that it is representative as opposed to the more reflective literary language, metaphors, analogies and other tropes have played a significant role in science writings from Ancient Greece and on.[93] Scientists in different periods working within different scientific disciplines have demanded different interpretations and uses of the various tropes employed in science. Opposed to literature, science is able to separate itself from language, because language to science: "[I]s merely a transparent vehicle through which it transmits to others its encounter with a lawful universe. The world presents itself to science not obliquely through language", as science historian

[93]It was, however, not until the renaissance that scientists became conscious of rhetoric and language-use as being a vital part of science and the communication of science (Naumann 2005, p. 516).

James J. Bono writes.[94] Thus, when we consider metaphors and other literary tropes, there is a fundamental difference between literature and science, although metaphors are a large part of both fields. This notion of a fundamental difference between science and literature fits well with the history of science section of the field of literature and science, as we shall see later.

Before the nineteenth century, no strict division existed between literary works and other types of writings; all texts were categorised as literature. Throughout the past centuries different types of texts have been linked to certain characteristics and the division between different types of writings has increased. Fiction and literary language had inadvertently been seen in connection with tropes, especially metaphors. Or at least imagery has been seen as essential to the construction of meaning in literature, whereas tropes in scientific writings have largely been seen as signs of the scientists' own ability to be imaginative, but not as something that fundamentally adds extra meaning to the text or theory.[95]

In some cases, literature will inadvertently rely on old established metaphors that accumulate and might change meaning over time. However, one will always be forced to consider the previous meanings of the words in order to get a deeper understanding of how the metaphor works in contemporary as well as past contexts. In the sciences there are also old and persistent metaphors, but when they change, they change for good — energy did not contain all the same connotation in Isaac Newton's time as in Albert Einstein's time. In the case of evolution, Darwin himself did not use the word evolution and the concept of survival of the fittest,[96] and it was not until decades later that the words were generally acknowledged and used. Hence, at least in connection to Darwin's works, once a new meaning of concepts is accepted old ones will only be of historical interest. This is opposed to literary language that may still play upon meanings of old metaphors. Also, it seems that many of the new metaphors and tropes established by the sciences in the nineteenth century were used in connection with the communication of sciences to the general public. Therefore, we need to take into consideration both the story of the original connotation of the words and tropes and the stories which later fostered new tropes and storylines.

When looking at the language of scientific texts it is of course also important to look at which role the various literary tropes play in the texts, both in relation to the individual text and the contemporary scientific context. As mentioned in Chapter Two, the language used in science writing, or what Shapin calls "literary technology", helped to convert science in the wake of the scientific revolution into an objective and authoritative undertaking, although science made great use of imaginative elements and literary devices and language.[97] In contrast to the general view of scientific language and scientific

[94] Bono 1990, p. 59.
[95] Otis 2002, pp. xix–xxi.
[96] The same goes for Maxwell's 'Demon', see Chapter Four.
[97] Clarke 1996, pp. 33–37.

practices of today, imagination was an essential part of the ventures of nineteenth-century science. This notion may be difficult to unite with the objectiveness that was also a fundamental part of scientific language-use. The imaginative meant that in the scientific texts: "[V]ision became a key metaphorical vehicle", as Laura Otis writes.[98] Thereby, scientists were forced to consider the meanings of different concepts and how these meanings had changed over time. But they also had to try and look forward into the future and imagine things smaller as well as larger than it was possible for the human senses as well as the human mind to perceive. In addition, as mentioned before, imagination in this respect also came to play a central role in connection to communicating science to an audience.

In Victorian scientific writings, different types of tropes became important vehicles. In general, tropes functioned as assistants to the scientific theory, which the text would convey by associating certain keywords with a particular theory. As Beer points out, Darwin in *Origin*: "[C]ulled his examples from a whole range of scientific specialisms: geology, botany, physiology, animal husbandry, natural history [...] cell-theory. And he further used analogy and metaphor to elucidate morphological resemblances within the natural order".[99] Darwin thus used language to support his argumentations, maintaining certain metaphors and analogies throughout the book connecting those to evolution.

Like other periods, the Victorian period was dominated by certain keywords associated with theories of the time. Keywords linked to physical forces such as magnetism, motion, heat, energy and electricity were all metaphors, which could be 'translated' from one scientific text (or scientific discipline) to the other. Hence, ideas could be conveyed through metaphors and analogies, and thus it was not only a way of making science more comprehensible to the public but an essential part of the scientific work.[100] However, tropes were also a help to the readers in order that they might better understand the scientific way of viewing the world by presenting concrete arguments in a familiar language.[101]

Returning to the subject of imagination, this can also be seen as a necessity for scientists' use of language because of the nature of language. Here we are faced with the fourth problem, which Beer points out in connection with Darwin's writings, namely the fact that language is anthropocentric. Beer writes:

> Certain conditions of language bear particularly hard on the scientific writer whose domain of inquiry, unlike that of literature, is not primarily or necessarily the human. Language is anthropocentric; it is also historically and culturally determined; it is never neutral; and it is multivocal.[102]

That is, language poses many possibilities of interpretation and to a scientist this could both be an advantage and a drawback. If not precise, one's choice of words could mean

[98] Otis 2002, p. 11.
[99] Beer 2000, p. 47.
[100] Otis 2002, pp. 9–11.
[101] For instance Darwin's use of plots and Maxwell's use of analogies, see Chapter Four.
[102] Beer 2000, p. 41.

a misunderstood text, but on the other hand it also could open up for more imaginative claims and ideas.

DARWIN's difficulties with language being anthropocentric also created another problem. One of DARWIN's main claims was precisely that the world was *not* anthropocentric, but that the human race should be regarded as a species alongside other animals. Therefore, DARWIN was faced with the problem of dismantling the anthropocentric worldview in an anthropocentric language.[103] Hence, there was an awareness of the nature of language as such, and that certain words, metaphors, etc., were not corresponding to the world that the scientific texts were describing. It did, however, bring about other possibilities and ways of getting the scientific message across, and, as mentioned above, being able to describe new mind-boggling theories demanded a flexible language.

Science Language and Language Science

Given that various tropes as well as figurative language have signified different aspects in different scientific disciplines and scientific writings, it will be impossible to give a full view of the role of literary language in science. In the field of literature and science, as well as constructivist history of science in general, there has mainly been a focus on the use of metaphors and analogies and to a lesser degree metonymies, allegories, etc. in scientific texts. Additionally, these works have to some degree mainly dealt with biology, geology and physics.

One should be aware of the fact that tropes in Victorian science were used consciously, while at the same time distinguishing the use of tropes in literature and the use of tropes in science: The tropes for the most part only functioned within the scientific context and rarely did the tropes only function as a literary expression.[104] On the same notion, BEER points out how one should deal with tropes in scientific writings and how these have to do with the predicaments when translating:

> Scientific ideas and writing are often most valued within literature precisely where the risks of translation are great. We should not look for one-to-one correspondences between scientific exposition and literary creation. Works of art press on the uncontrolled implications of science, while new scientific ideas, theories, and products make it possible to articulate what has earlier been taken for granted (and therefore was not available to be recounted, so embedded was it in assumptions beneath the level of description.) Sometimes the level of allusion vanishes again as scientific theories change.[105]

The position that tropes found in scientific texts should be seen in their own right in their historical context and not as literary relics, most writers in the field of literature and science agree on. However, within the field there are still considerable differences in the

[103] Beer 2000, pp. 45–46.
[104] Naumann 2005, p. 516.
[105] Beer 1987, p. 52.

views and analyses of tropes and imagery in scientific texts. The rising interest in tropes in science writings is usually focused on the way in which tropes have had an importance for how science is communicated, how tropes can present additional meanings in the texts and, on a more radical notion, how tropes and imagery can create science.

Once again, there is a noticeable division between how literary critics and historians of science in the field of literature and science deal with language in scientific texts. Most scientists in the field see tropes and the scientist's conscious use of tropes as part of the current language-use in the particular scientific area and as a way of communicating the scientific message to the reader (whether the general readers or other professional scientists). As mentioned previously, the literary critics working within the field of literature and science often have a deconstructionist approach also when it comes to the composition of and language-use in scientific texts: Tropes and linguistic imagery in a scientific text should therefore be seen as a 'completeness' in itself and not necessarily referring to the world outside the text. A prominent example of the deconstructivist reading of tropes is Beer's reading of Darwin's *Origin*. Beer analyses the *Origin* as a work written within a language that did not fit the author's theories and therefore will result in:

> [T]he feeling of thisness of things [including words] which signals both their full presence and their impenetrability, their freeplay, their resistance to interpretation in terms of man's perception and needs, and yet man's profound need to join himself to them which may be expressed linguistically through metaphor.[106]

Consequently, Beer argues that Darwin's words were independent of the world he described since this world could not be described in the existing language. Darwin's work therefore consists of interrelating words and tropes.

Despite of the analytical differences in the field of literature and science there are two general points of interest, when it comes to views on tropes. The first notion revolves around the issue of whether a trope controls the scientist or the scientist is in control of his tropes. This notion, which stems from the first studies in science and tropes, is particularly important for the studies on metaphors (see below). The second notion has to do with viewing tropes as a new scientific instrument, meaning that certain tropes will have a concrete role in the scientific message.

The literary historian Barbara Naumann writes on tropes in scientific writings and especially on how metaphors and other literary elements in scientific texts can be viewed as categories.[107] According to Naumann, metaphors and other tropes can be regarded as categories in scientific texts and thereby have significance for the theories and meanings communicated in the individual text.[108] Representative of the historians of science in the field of literature and science, Gross views Darwin's evolutionary language as a form

[106] Beer 1986, p. 221.

[107] With the scientific revolution scientific disciplines developed and made great use of especially Linnaean categorisation and classification (Bowler and Morus 2005, pp. 444–445).

[108] Naumann 2005, pp. 513–514.

of taxonomy or category in which the new order of nature that Darwin sets out can be placed. Darwin's evolutionary language could be used as a new form of categorisation of the world and thus is not only describing the world, but also predicting how evolution will influence nature.[109]

Metaphors and Analogies — Definitions

Metaphors have always been present in scientific texts, but one can divide the views of the metaphor in science into two main theories: The metaphor as substitution and the metaphor as interaction. The theory of the metaphor as substitution is the standard view of the use of metaphor in science. Around the sixteenth century, the literal and figurative levels of language were separated, and science came to be identified with a literal language use.[110] A metaphor, therefore, could only be a figurative substitution for a literal or 'real' meaning. Many theorists believe that the metaphor: "[I]ntroduces inappropriate, non-literal meanings into science, contaminating the precise and stable meanings science attempts to discover behind the terms it uses", as Bono puts it.[111] Therefore, the metaphors, and indeed other tropes, were and are still not favoured in the scientific language. Most metaphors used in scientific texts, especially in the last century, have been dead metaphors, which stem from either other areas of science or from older scientific findings or texts.[112] Metaphors were used in the texts, but it was believed that science was in complete control of the language and the meanings produced by the language.[113]

Now we turn our attention to metaphors as interaction and not merely substitution. From the middle of the twentieth century new understandings of the metaphor's role in science have been put forward, which later influenced especially the literary side of the field of literature and science. As mentioned in Chapter Two, since the 1960s constructivism has played a significant part in the history of science, and the nature of language and metaphors was also looked upon from a constructivist angle. At that point in time, the metaphor was seen as a significant part of the scientific language. And even in highly specialised theoretical texts the metaphors play an important role. Thus, some theorists began to view the metaphor as vital to the constitutive elements of a scientific theory and not as a threat to science or the meaning that science generates.[114]

Up until the beginning of the twentieth century, metaphors generally were seen as ambiguous and, at the best, momentary. Scientists in the nineteenth century were con-

[109] Gross 1990, pp. 33–39.

[110] In for instance occult science of the Elizabethan age, there was no distinction between the literal and the figurative language and words were therefore treated as equal to the words they substitute (Bono 1990, p. 61).

[111] Bono 1990, p. 62.

[112] In addition, scientific text and language from the beginning of the twentieth century and on has also relied on strict analogies, for instance the letter sequence U-U-U can be seen as a concrete analogy of a particular structure in the DNA (Gross 1990, p. 29).

[113] Bono 1990, pp. 60–62.

[114] Naumann 2005, pp. 516–517.

scious about their metaphors, the use of them, and the use of the metaphors in connection with the scientific models.[115] Metaphors are probably the most common trope used in scientific writings and often fills out gaps in the vocabularies of science, especially when new scientific paradigms surface. Some metaphors start out by representing certain facts, but will in the course of time transform into symbols or will mean something entirely different from their original meaning.[116] Analogies as well, have also been used in numerous scientific writings throughout the centuries: Especially because an analogy can serve as a rather simple illustration of complicated scientific argument. Through the analogy, one can compare complex scientific arguments with situations or structures from everyday life, which gives a sense of an ordered universe. This notion was in particular common in natural theology up until the nineteenth century, because it was easy to argue for a designer behind nature — that is, an order that could be seen in nature, science and life in general.[117]

Most writings on science in relation to language do not clearly distinguish between metaphors and analogies, and therefore when treated below, metaphors and analogies will be included in the same section. Naturally, however, the specific distinctions between metaphors and analogies have been dealt with. Beer writes with reference to Darwin that metaphors were actively used to say more than was intended; whereas analogies were tools used in evolutionary theory throughout the nineteenth century and were becoming part of the theory and not just a linguistic tool.[118] Thereby, Beer views analogies as shared devices amongst scientists in the same scientific field, whereas metaphors are more likely to be attributed to the individual scientist and what he is trying to convey through his text.

Another way of viewing the analogy as opposed to the metaphor is by considering the illustrations or graphic representations in scientific texts as analogies. In the beginning of Darwin's *Origin* there is a diagram illustrating evolution, which not only is reminding of branches of a tree but also in fact becomes a tree (see *Figures 3.2* and *3.5*). Darwin's tree is used as an elaborate metaphor for evolution and it is thus not a coincidence that the diagram looks the way it does; the graphical depiction not only reminds of something, it actually becomes that something (*Figure 3.5*). Darwin employs several metaphors of trees, webs, kinship, ancestry, hierarchy, etc., throughout *Origin*, where he also uses the tree and web analogously in connection with diagrams. In the end, the tropes are the source of creation rather than description, which is not exclusive to the case of Darwin, I will argue; with metaphors and analogies scientists had a tool to develop their theories. Furthermore, there is an additional aspect to notice in connection with this cluster of tropes: A common feature of the metaphor and analogy is the expression of kinship. Additionally, they disrupt hierarchy, something that was the cornerstone of evolutionary

[115] Brody 1987, p. 47.
[116] Norwick 2006, pp. xiii-xiv.
[117] Beer 2000, pp. 76–77.
[118] Beer 1986, pp. 238, 242–243.

biology, too.[119] In the case of Darwin, metaphors and analogies beget an additional layer of meaning, a feature that will be explored in concrete examples below.

Metaphors as Substitution and Interaction

Both historians of science and literary critics in the field of literature and science recognise the diversity of individual metaphors, scientists and different contexts, and as such view metaphors in their own right. But once again, we witness a fundamental difference in their views of the mechanisms of scientific texts. Occasionally, the scientists are in control of their metaphors, Richard Boyd argues: Metaphors are sometimes, as he calls it, intra-scientific, that is, metaphors that we can, as Bono describes Boyd's thesis: "[T]race back to an 'original' use *within* science itself. That is to say, the metaphoric exchange occurs either within one scientific discipline or between two or more disciplines of science and technology".[120] An example of an intra-scientific metaphor is how a computer can be used as a metaphor for the brain. With the intra-scientific metaphor meaning stays within the scientific discourses, according to Boyd.[121] The problem with this analysis of the metaphor is that there will always be some inferred meaning in expressions like computer and brain that will not only have scientific implications, but also cultural, sociological, etc. However, in my view, it is probably the closest science gets to control its metaphors.

Turning to the metaphor as substitution, in an article on metaphors Boyd argues that the metaphor's role in scientific texts is vital also in the process of creating theories. Boyd relies on the theories of Mary Hesse and others,[122] who argued that metaphors and analogies were a natural part of science because they had the abilities: "to be suggestive of new systems of implications, new hypothesis and therefore new observations".[123] Metaphors create new meanings but never permanent ones and therefore they are also able to contribute new meanings to the scientific facts and theories. Boyd distinguishes between so-called literary metaphors and scientific metaphors. By literary metaphors, he refers to the creativity of the individual writer of a text. These metaphors will often only be found in that particular text and will often not create opportunities for further research.

On the other hand, the scientific metaphors are properties of the scientific community and can be found in many texts. These scientific metaphors will be able to generate strategies for further research, because the scientific community would want to investigate further into the meaning of their shared metaphors. However, as Boyd points out, the literary metaphors will often be the kinds of metaphors that will be investigated and analysed by literary critics, because it says something about the scientist and his view of the world.[124] Metaphors can thus both be seen as an expression of the individual

[119] Beer 1986, p. 238.
[120] Bono 1990, p. 73.
[121] Bono 1990, pp. 72–74.
[122] See Chapter Two, p. 27.
[123] Quoted in Bono 1990, p. 71.
[124] Bono 1990, pp. 63–64.

scientist's creativity, but also as a way of "initiating and controlling novelty", as Beer puts it.[125]

The fact that the nature of the metaphor results in meaning becoming somewhat unstable also came to have significance to the scientific explorations of the nineteenth century. Since many scientific disciplines were just starting to get their own individual nomenclature and interpretations of words and objects in nature, metaphors were an excellent way of constructing more stable meanings within a certain scientific discipline.[126] This could be done precisely because the connotations of the metaphors were already unstable and therefore scientists could use certain metaphors to establish a more stable meaning to use in a particular field or sets of theories. In this respect, science's use of categories, as mentioned above, also benefitted from the use of the metaphor. Metaphors could assist in establishing certain categories in order to develop more stable meanings within the categories but also open up for further development. Consequently, categories in science would be characterised by certain concepts and metaphors.[127]

The metaphor has also had an enormous impact on the various scientific discourses. As Bono makes a point of:

> Rather than mirroring the 'legible face' of a reality envisioned by scientists and 'deciphered' within a single, dominant paradigm, complex scientific texts and discourses constitute themselves through their intersection with other, multiple discourses.[128]

Metaphors have helped bringing scientific discourses closer in relation to other discourses, for instance social and cultural ones, because the metaphor in a given scientific text will also tell us something about the contemporary context, be it scientific and non-scientific. In a present day context the metaphor, according to Naumann:

> [I]s not only a pictorial and direct expression of scientific facts that exist independently of their representation. The metaphor marks a process of translation that the movement of thought itself represents, and it thus affects the scientific orientation within which it appears.[129]

This translation mentioned in the quotation is often where theorists in the field of literature and science will centre their analyses, because perspectives on the context will be clarified here.[130] The metaphor's impact on science was even more predominant in the science writings of the nineteenth century, as we shall see below, but first it is important to differentiate between the ways in which metaphors in science are seen.

A typical literary reading of metaphors is evident in Bono's view of the metaphor (see above), which to some extent is inspired by deconstructionist theories especially

[125] Beer 2000, p. 89.
[126] Beer 2000, p. 47.
[127] Naumann 2005, p. 516.
[128] Bono 1990, p. 61.
[129] Naumann 2005, p. 517.
[130] Naumann 2005, p. 517.

those of JACQUES DERRIDA (1930–2004). In his essay "Science, Discourse, and Literature: Role/Rule of Metaphor in Science", BONO questions the role of the metaphor: Is it the scientist or the author who is in control of the metaphors, as suggested by BOYD, or is it the metaphor that rules? On the one hand, scientists have a special insight in a particular field and in nature as such, and they are therefore able to control certain metaphors and utilise them to construct a particular scientific discourse. On the other hand, however, metaphors might present several meanings and more connotations beyond the boundaries of the particular scientific discourse. BONO, himself, is inclined to believe that the metaphor rules the scientist more than vice versa. Hence, metaphors will always create new meanings and also need new translations.[131,132]

Metaphors and Evolutionary Theory

According to BEER, DARWIN saw metaphors as not just a linguistic flavour or random comparison. DARWIN carefully chose his metaphors; to him they were part of his theory and sometimes corresponded very closely to what he described. Thus, the metaphors were part of the creative process. The view held by many historians of science of the field concerning the metaphor is that the metaphor becomes almost a concrete tool, alongside with the analogy, which can be used in further research. Furthermore, it is seen as an expression of the scientific creativity on behalf of the scientist. Using the metaphor as a form of steppingstone is commented on by BEER — she writes on DARWIN:

> Darwin needed a metaphor in which degree gives way to change and potential, and in which form changes through time. He did not simply adopt the image of a tree of similitude or as a polemical counter to other organisations. He *came upon it* as he cast his argument in the form of diagram.[133]

Providing his arguments with a concrete metaphor thus helped DARWIN to further his argumentation. The metaphor almost became real and thereby a valuable and almost empirical tool to him. This notion of the metaphor is particularly interesting in dealing with the nineteenth century, as will bee exemplified in HUXLEY's chalk article.

The fact that DARWIN's texts were filled with complex and intertwining metaphors cannot be disputed and it will be impossible to describe all of his tropes in detail. The most well-studied of his metaphors are those of the 'entangled bank' and the web or tree as the concept of natural selection, all briefly described previously in this chapter. The metaphor of natural selection is in this respect somewhat different from the other metaphors. The concept of natural selection is in many ways a radical notion because it assumes that there is someone that selects, and in order for DARWIN to prove this

[131] A similar view is presented in YOUNG's book *Darwin's Metaphor* (Young 1985), in which he argues how one of DARWIN's central metaphors in *Origin* changes meaning in the course of his works, and how his metaphors became an important part of the way in which his theories were communicated. YOUNG's view on DARWIN is dealt with in Chapter Three, p. 43.

[132] Golinski 1998, pp. 123–125.

[133] Beer 2000, p. 33.

new theory of natural selection he had to use known metaphors. These metaphors were mostly dead metaphors and taken from other sciences, and at some point he even refers to NEWTON in order to invoke authority.[134] Hence, it was both the concept of natural selection DARWIN had to communicate and, more radically, had to teach his reader to understand metaphors as a force, which also bore meaning. In addition, some critics have agued that by setting standards for new types of metaphors and analogies, DARWIN wrote against the discourse of natural theology including the religious implications in the language of natural theology. According to DARWIN, it was no longer a divine creator who was in control of the metaphors and analogies, it was the scientist himself who could create metaphors that would fit his theory and outlook on nature.[135]

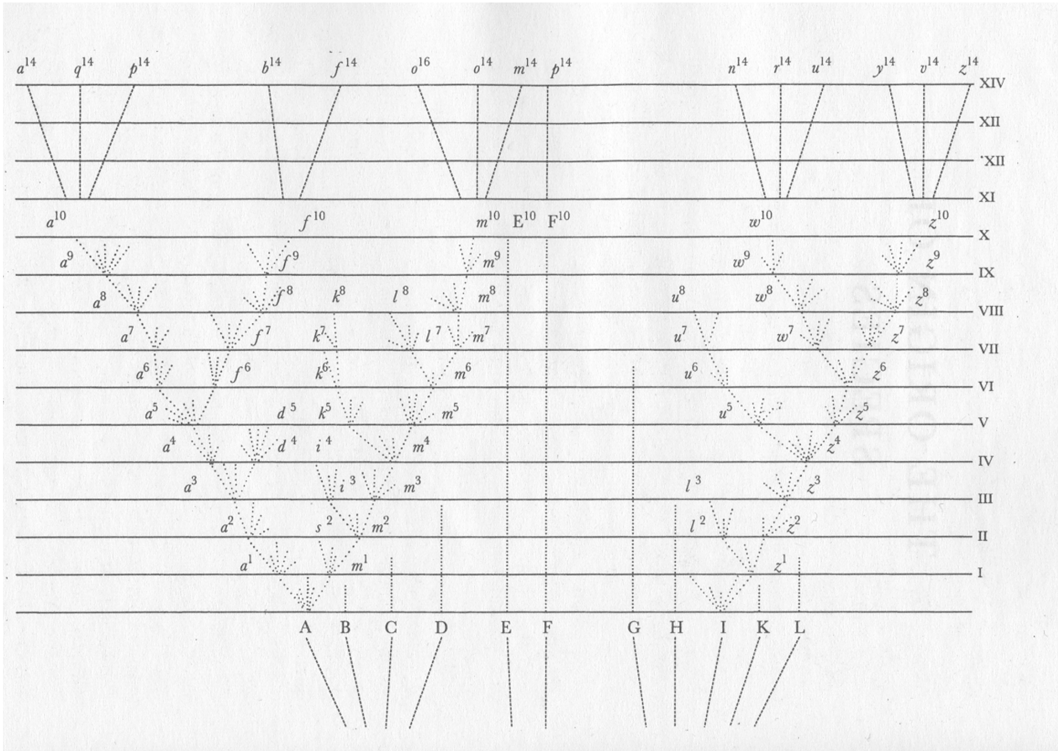

Figure 3.5: This tree is depicted in the introduction of DARWIN'S *Origin and in many ways resembles the tree* DARWIN *scribbled in his notebook on the Beagle-voyage (see Figure 3.2).* DARWIN *is thus seen to hold on to the metaphor of the tree throughout the development of his theory of evolution. (Source: Darwin 1998).*

HUXLEY'S article on chalk contains both metaphors and analogies. Most noticeable are his analogical references to DARWIN'S story of evolution of the species, which HUXLEY compares to the evolution of chalk. In the same way in which DARWIN uses his metaphors and analogies to prove evolution, HUXLEY uses DARWIN to support his story about chalk. Looking at some of the metaphors that HUXLEY employs, two of them stand out in particular. In the beginning of his article, HUXLEY uses a metaphor of language; the history of the world, he states, is written in chalk. With this metaphor, HUXLEY also indicates that his

[134]Beer 2000, pp. xxiv–xxv.
[135]Levine 1991, pp. 115–116.

chalk language (and thereby in the end also evolutionary theory) is able to uncover all nature's secrets when read or interpreted.

Another metaphor that Huxley uses is also found in Darwin's *Origin*, namely the metaphor of growth and transformation or metamorphosis. In Darwin's evolutionary theory, transformation naturally plays a vital role, since transformation more or less equals evolution. Many of Huxley's metaphors and analogies are tropes of metamorphosis; for instance, he describes in a very poetic language what happens when a piece of chalk is placed under a microscope and the observer peeps into a different kind of world. Darwin and Huxley's metamorphosis metaphors are not merely poetic references to for instance Ovid's (43 BC–c. 18 AD) work, but they are themselves proofs of metamorphosis in nature in accordance with evolutionary theory.[136] Thus, both tenor and vehicle of these particular metaphors refer to actual processes in nature.

Most writers in the field of literature and science agree that Darwin's scientific style moves "beyond words",[137] as James Krasner writes. He continues to sum up Darwin's use of metaphors and analogies:

> Darwin's scientific prose [...] moves beyond vision, by allowing the individual form, whether it be a pigeon, a mountain, or the word *species* itself, to expand past its own boundaries into a multitude of other possible forms. The edgeless analogical multiplication is crucial to Darwin's conception of nature, and his visual rhetoric allows the reader to experience evolutionary flux imagistically, as it were to image the unimageability of a continually changing natural world.[138]

These are images and tropes that can create rather than describe and which in their essence fit well in with Darwin's evolutionary theory: According to these readings of Darwin, there are no metaphors of mere substitution but only of interacting, which in the end help his theories grow.

Beer calls Darwin's use of metaphors "romantic materialism", because he almost wanted the metaphors to become real, that is, to transform the imaginative into something concrete and materialistic. But it was not only on a more general level that Darwin's metaphor received a new meaning; also on the level of the language it had a fundamental impact, as Beer writes: "[Darwin] used analogy and metaphor to elucidate morphological resemblances within the natural order".[139] Accordingly, the imaginative powers of the scientist and in science in general were indeed important, as previously mentioned, and the metaphors became a tool for the scientists to use in creating links between new and often amazing theories and increasingly empirical scientific methods.

[136] Beer 1986, p. 237.
[137] Krasner 1990, p. 140.
[138] Krasner 1990, p. 140.
[139] Beer 2000, p. 47.

Metonymies and Allegories

Contrary to metaphors and analogies, tropes like metonymies and allegories have been treated secondarily in the writings on Darwin and evolutionary theories. In the case of thermodynamics, there has been a greater focus on metonymies and metaphors. There are a few standard definitions of metonymies in science to be found, and so far, to the best of my knowledge, no detailed accounts of either the role of metonymies or allegories in science have been written. The reason they are mentioned is because there are occasional reference to both metonymies and allegories in the works written on literature and science. The question of why metaphors and analogies have been favoured compared with metonymies and allegories will also be addressed in Chapter Four.

In Gal's article "Tropes and Topics in Scientific Discourse", he offers a standard definition of the metonymy, as one word substituting another.[140] Seeing this as more or less a standard definition of the metonymy in scientific writing it would seem that the metonymy takes over one of the roles of the metaphor as mentioned above, namely the role of substitution as opposed to interaction: One word may be as good as another and will not create additional meaning to the text. In the end, the metonymy, in this version, is much more controllable than is the case with the metaphor. In this respect, one might expect more use of metonymies than metaphors.

Similarly to the studies of metonymies, allegories have not been subjected to many detailed explorations. In the scientific tradition, allegories have been used widely and often as an explanatory device or as a heuristic tool to make testable models.[141] In his article on allegory in science, the literary historian and President of the *Society for Literature, Science, and the Arts* Bruce Clarke has a brief historical account of rhetoric and tropes in science. Clarke writes on the allegory:

> Allegory emerged when systematic reasoning was applied to archaic cultural narratives; science emerged when the abstractive attitudes of allegorical reading were extended to the contemplation of the natural world. And ever since Plato there has been this discursive recursion, this alternating historical current: first science develops from allegory, then allegory develops from science.[142]

Already prior to the Scientific Revolution, science was interlocked with allegory. Allegories are usually linked to a mythical structure projected upon a narrative. And through history, tropes and literary language have helped scientists to convey their message to the audience. By using the allegory, science would fit in with other cultural narratives and fit in with a religious view of the world. In a nineteenth-century context, the allegory could be used actively to promote a specific scientific theory or a specific outlook on nature. This is the case with Darwin, who contrasted *Origin* and the evolutionary theory against

[140] Gal 1994, p. 31.
[141] Bono 1990, p. 61.
[142] Clarke 1996, p. 33.

the stories and the discourse of natural theology, and thereby also against the use of allegory in older scientific writings.

Why the metonymies, allegories and other minor tropes have not been of as great interest as metaphors and analogies may seem odd, since precisely the metaphors and analogies are more unstable and uncontrollable than other tropes when it comes to meaning. In view of the nature of the metaphor and analogies, one should think that scientists were interested in conveying a precise message and therefore employ more stable tropes like metonymies. But in the case of scientific texts about evolutionary theory, the metaphors and analogies certainly by far outnumber other tropes. However, even though there is not for instance a wide-ranging allegory in texts on evolution, allegories are important to keep in mind when analysing nineteenth-century scientific texts: Metonymies as controllable tropes reflect the nature of scientific practice and allegorical storylines that can be traced back to scientific texts of preceding centuries and either employed or written against.

Tropes in Retrospect

When it comes to analysing linguistic elements in scientific writings, the writers within the field of literature and science have increasingly taken an interest in various tropes and literary imagery. Especially the literary critics have excelled not surprisingly in writings on the linguistic nature of the scientific texts. Some critics have even gone as far as to claim that language alone makes science. In addition, many critics have also seen a work like Darwin's *Origin* as a purely literary work, even though many, especially historians of science of the field will maintain that Darwin's work first and foremost is science and not purely a sum of linguistic practises. Furthermore, it is clear that both Darwin and evolutionary theory have been the subject of most of the works on the tropes of Victorian science. Because the Darwin-case focused on tropes, they have also dominated other cases.

Taking a look at the individual tropes in scientific texts some tropes have drawn more attention to themselves than others. Even though tropes like metonymies and allegories have not been paid much attention, I have still included them because I will return to them in Chapter Four dealing with the case of thermodynamics, where the allegory at least, plays a more important role. The metaphor, however, is by far the most popular trope to analyse in relation to science writings, closely followed by analogies. Two main views on the metaphors have been characteristic of the analyses of the metaphor, which mimics the fundamental conflict of the field of literature and science: The metaphor in view of control and of categories. Critics have posed the question of whether the metaphors employed in scientific writing are in control of the scientist or whether the scientist is in control of the metaphor. Hence, the metaphor may be viewed as either a tool of communication, where the scientist is in control, or as a tool of creation, where the metaphor sparks new meanings which cannot be completely controlled by the scientists. The other main view on metaphor concerns categories; herein metaphors are viewed as a kind of scientific tool that can help make new types of scientific categories and thereby also create new scientific knowledge.

3.5 Facts and Figures of Science

Throughout this chapter, I have sought to outline the many details of the case study of Darwin and evolutionary theory and take into consideration the diversity and positions (and oppositions) within the field of literature and science. The way I have chosen to structure the examination of the case, with the contextual level, textual level and the level of language, respectively, is very broad but also includes all of the overall aspect I have come across when reading the articles and books produced by the writers within the field of literature and science. The choice of Darwin and evolutionary theory as a case study for this chapter is not coincidental. Darwin and evolutionary theory have been a quintessential point of reference in the studies of the relations between literature and science in the Victorian Period. Furthermore, the case of Darwin and evolutionary theory has also proven fruitful in an investigation of how writers within the field of literature and science have dealt with Victorian scientific texts.

Though I have focused on the main oppositions in the field, my point is also to make clear that despite of differences the writers in the field agree on many aspects of the relationship between literature and science, and it is in this ford between the two disciplines that the analyses become interesting. The main difference between the literary critic section and the historians of science section in the field is quite fundamental and in general concerns whether science should be viewed as a cultural construction or as culturally determined. Thus, it boils down to two extreme positions, seeing science as independent of language (the strict deconstructivist approach) or dependent of language (where the scientific language is fixed to the particular time period). Hence, one might say that the literary section of the field seeks an epistemology of the relations between science and literature, whereas the scientific side opts for a rhetorical approach.

The fundamental division in the field is to a great extent visible in the Darwin-case, but bears significance in other cases as well. It is clear, however, that the case of Darwin and evolutionary theory has assisted in setting standards for how the relations between science and literature should be interpreted. But as suggested in the last section of the chapter on language, the Darwin-case cannot function as a perfect model which will be illustrated in the next chapter, where it will be discussed whether or not the case of thermodynamics is a fundamentally different case from the Darwin-case. I will approach the case of thermodynamics in light of the analytical model outlined in this chapter on the basis of Darwin and investigate how the contextual and textual alongside with the language-use and tropes constitute the case of thermodynamics.

Chapter Four

The Literacy of Thermodynamics

> Then star nor sun shall waken,
> Nor any change of light:
> Nor sound of waters shaken
> Nor any sound or sight:
> Nor wintry leaves nor vernal,
> Nor days nor things diurnal;
> Only the sleep eternal
> In an eternal night.
>
> From A. C. Swinburne, "The Garden of Proserpine", 1866

In this chapter, I will focus on one of the other grand scientific narratives of the nineteenth century, namely thermodynamics. The main focus of this chapter is to find out whether the analytical model established in Chapter Three can be employed successfully to the case of thermodynamics. In addition to the examination of how the analytical model relates to the case of thermodynamics, I will briefly look into how thermodynamic texts have been analysed by historians of science and literary critics of the field of literature and science. In particular, I will investigate whether the fundamental conflict between the historians of science and literary critics documented in previous chapters has also carried over into the case of thermodynamics. In the last section of the chapter, I will use one of James Clerk Maxwell's central texts to bring forth Maxwell's own view of the interrelations between literature and science.

The three levels of which my analytical model consists — the contextual level, the textual level and the level of language — will play a smaller role in this chapter in order not to repeat too many points from Chapter Three. Given the substantial works written on Charles Darwin and evolutionary theory, the Darwin-case has set many standards for how nineteenth-century scientific texts could be viewed in relation to literature. These standards, no doubt, also have had an influence on the case of thermodynamics. Particularly on the contextual level, many parallels exist between the case of thermodynamics and evolutionary theory. These parallels are actually independent of the modes of analysis employed by the writers within the field of literature and science. Also on the textual level and the level of language there are similarities between the two cases, both in relation to the usage of character, storyline and of particular tropes. The similarities between the case of thermodynamics and evolutionary theory will be dealt with only briefly in this chapter. Instead, the main emphasis here will be on the differences between the cases, and whether these differences make the case of thermodynamics incompatible with the analytical model.

Within the history of science, the theories of thermodynamics have been treated as equally important scientific conquests as the theory of evolution. Within the field of literature and science, however, thermodynamics has not attracted as much attention as DARWIN and evolutionary theory. During the past ten years or so, the literary scholarship on thermodynamics has increased and literary critics (including a key writer like GILLIAN BEER) have taken an interest in the scientific writings of the theorists of thermodynamics. Most often, individual essays and articles on thermodynamic theory are to be found in general works or anthologies on nineteenth-century science and literature.[1] In contrast to the many works on DARWIN, comparatively few works have focused exclusively on thermodynamics. I want to emphasise two of the most noticeable works on the connections between literature and thermodynamic science. Published in 2001 and 2002, the books *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* and *From Energy to Information: Representation in Science and Technology, Art, and Literature* presented new views on thermodynamics in a cultural context. *Energy Forms* is written by BRUCE CLARKE and examines the allegory in works by scientists of thermodynamics, mostly MAXWELL. *From Energy to Information* is edited by CLARKE and LINDA D. HENDERSON, and the book investigates the relationship between science, literature and art from the age of thermodynamics and forward. Their investigation into the relationship between science, technology, literature and art takes an interdisciplinary approach to the theme of transitions, but still focuses on the historical development and contextual influences of science, technology, art and literature. Thus, neither of the two books is a systematic investigation of for instance MAXWELL's scientific writings, but rather takes up thermodynamics as a general theme for several scientists in both the nineteenth and twentieth centuries.

The works on MAXWELL's scientific writings in relation to literature differ in many ways from the works on DARWIN's writings. The works on MAXWELL and thermodynamic theory usually take up central elements such as entropy or energy, and analyse these in relation to literary and scientific works of the nineteenth and twentieth centuries. Hence, the focus of the analyses of literature and science has shifted when it is applied to the work on thermodynamics; in the end, this may also influence how my analytical model fits the case of thermodynamics. It may be the case that because the Darwin-case has dominated the readings of nineteenth-century scientific writings, the writers who have taken an interest in the case of thermodynamics have deliberately moved away from the way in which the Darwin-case has been treated. Another possibility why the case

[1]For example HAYLES' essay "Self-Reflexive Metaphors in Maxwell's Demon and Shannon's Choice: Finding the Passages" (Hayles 1990b).

of thermodynamics has not attracted as much attention from the field of literature and science as the Darwin-case, is that perhaps there is less to be said about literary devices in thermodynamics than in the Darwin-case. This will remain to be discussed in the following.

The Texts of Thermodynamics

The focal points of this chapter will be on texts by MAXWELL and WILLIAM THOMSON. In the following, these texts will be utilised to illustrate both central similarities and dissimilarities between the Darwin-case and the case of thermodynamics, bearing in mind how the writers in the field of literature and science view nineteenth-century scientific writings. The thermodynamic texts by THOMSON and MAXWELL fit well into the analytical model as a whole, but in order to keep a focus, I have chosen to concentrate mainly on the textual level with minor references to the contextual level. Concerning the level of language, it was pointed out in Chapter Three that contrary to evolutionary theory and DARWIN, the thermodynamic texts rely more on allegories and metonymies than metaphors and analogies. This aspect has been dealt with in most of the books and articles on the literary influence on thermodynamics, in particular the works of CLARKE. I will not go into detailed analyses of individual tropes in this chapter, but deal with this aspect in general. However, it is worth noticing that MAXWELL, himself, wrote on analogies (see below) and it may therefore seem odd that so little has been written on MAXWELL's use of analogies. It is my argument that MAXWELL is, indeed, very conscious of his use of analogies as will be discussed in the following.

I have chosen to focus on four key texts, three texts written by MAXWELL and an article by THOMSON.[2] THOMSON's text is included partly because it is a key text of thermodynamic theory and an overall narrative, and partly because THOMSON played a significant role in relation to MAXWELL, who was greatly inspired by THOMSON's work. The first of the four texts to be discussed is thus THOMSON's article "On the Age of the Sun's Heat", which was published in *Macmillan's Magazine* in 1862. THOMSON's article introduces the quintessential notions of thermodynamic theory and — more or less — describes how the world will come to an end. After discussing the text by THOMSON, I want to address two texts by MAXWELL. The first is an extract from his book *Theory of Heat*, 1871, which is one of the fundamental works of thermodynamic theory. In this particular extract we are introduced to MAXWELL's being, or Demon, as THOMSON afterwards named it. The second text by MAXWELL is the article "Molecules", which was published in the scientific magazine *Nature* in 1873. In that article MAXWELL coined and described the concept of molecules and molecular science.

In connection with the last section of the chapter, I will take a look at MAXWELL's article from 1856 "Are There Real Analogies in Nature", in which MAXWELL presents his

[2]In many respects, the article by THOMSON will function in the same way as the article by HUXLEY did in Chapter Three in relation to DARWIN.

view on literary language and its place in scientific writings. In that article MAXWELL discusses the nature and role of analogies in science. The text was originally a lecture he gave to the elitist Cambridge debate group *The Apostles*. As was the case with the texts used in the Darwin-case, the texts included for discussion in this chapter are all written in a non-scientific language, although only THOMSON's article and MAXWELL's article on analogies are specifically targeted to a non-scientific audience. As mentioned before, it was not uncommon in the Victorian Period for some professional scientific texts to be written in a language understandable to others than scientists, however the articles in this chapter are some of the most 'reader-friendly' texts produced on thermodynamics in that period.

4.1 Thermodynamics in the View of the Field of Literature and Science

As already mentioned, the theory of thermodynamics has not been able to draw as much attention to itself as evolutionary theory when it comes to studies of how science is influenced by literature. Still, the theory of thermodynamics has been the second largest field of interest when it comes to analysing the interrelations between literature and science of the nineteenth century. And given that research into the literary history of science has only taken off within the past decades, it may well be that the future will bring more detailed studies into thermodynamics. Another possibility is, of course, that thermodynamic theories may not be as suitable for literary analysis as DARWIN's body of works and that the few texts by MAXWELL that have been studied are only exceptions. In general, MAXWELL is treated only in the books that have a general view on science and literature in the nineteenth century, but even here he is vastly surpassed by DARWIN.

The works analysing thermodynamics naturally rely on previous works written within the field of literature and science, especially when it comes to dealing with the nineteenth-century context and how science and society relate to each other. In this respect, the discussions presented in the contextual level of the analytical model will also apply to the case of MAXWELL and thermodynamics. Hence, it is in the details that we may uncover new perspectives to challenge the Darwin-case. For instance, language and narrative structures have been given more focus in connection with thermodynamic texts. And as we shall see below, the language of thermodynamic writings is welcoming analyses focusing expressly on linguistic elements and individual tropes. Hence, it will not be on the contextual level that the analyses of thermodynamic texts differ from the analyses of evolutionary theory texts, but rather on the levels of language and textual elements.

4.2 Thomson's Narrative of the Age

In this section, I discuss THOMSON's article "On the Age of the Sun's Heat" in specific relation to the writer's worldview, the storyline, the narrator and the attentiveness towards the audience of the texts. All these subjects refer to the textual level in the analytical model and are subjects where apparent similarities are to be found between the Darwin-case and thermodynamics. Whereas the evolutionary writers deal with the evolution of the species, THOMSON in his article tells the story of how and also when the world is going to end. Thereby, in a sense, he abruptly cut off the evolutionary narrative. In the 1850s, THOMSON formulated the second law of thermodynamics,[3] which led him to the conclusion that the sun would at some point burn out.

The gradual loss of the sun's heat, which in the end would mean the end of life on Earth, was a controversial theory at the time. Not because people were not used to the idea of a form of apocalypse, but this notion had hitherto belonged to the religious interpretation of the world.[4] In his article it is clear that THOMSON strives towards explaining to a non-scientific audience how the theory of the sun's heat works. THOMSON clearly upholds an objective language and attempts to establish his own authority from the start of his article. He begins by giving a fairly scientific introduction to the second law of thermodynamics and the theory of the heat of the sun. However, hereafter he makes it clear to his audience that he wants first and foremost to explain the components of the theory and the consequences which the loss of the heat of the sun will have.

There can be no doubt that THOMSON's article was aimed at a non-scientific audience. As previously mentioned, popular science writings of the Victorian Period played a large role for both scientists and their audience because of a fundamental understanding between author and reader. As BEER observes with explicit reference to "The Age of the Sun's Heat":

> To most intelligent Victorian readers physics could become intelligible only in a popular conceptual form. Moreover, the absence of a formal scientific education meant that scientific ideas tended to be received by non-scientific Victorians in the mode of dread and dreams as well as intellectual conundrums. The result is that ideas of 'force' and 'energy', arguments concerning the age of the earth and the cooling of the sun, passed rapidly into an uncontrolled and mythologized form. In addition, prominent Victorian scientists saw it as part of their function to impart their ideas to untutored readers in an accessible form and so wrote [...] for general cultural journals.[5]

[3]See Chapter One, p. 5.

[4]The 'death of the sun' alongside with the concept of entropy (i.e. the movement towards greater molecular chaos where, according to the second law of thermodynamics, the increasing entropy will result in a static state when energy can no longer be transferred) became very popular themes in Victorian fiction. In the end of WELLS' *The Time Machine* (Wells 1971), the main character reaches a point in the future when the world has reached the entropic state.

[5]Beer 1996, p. 228.

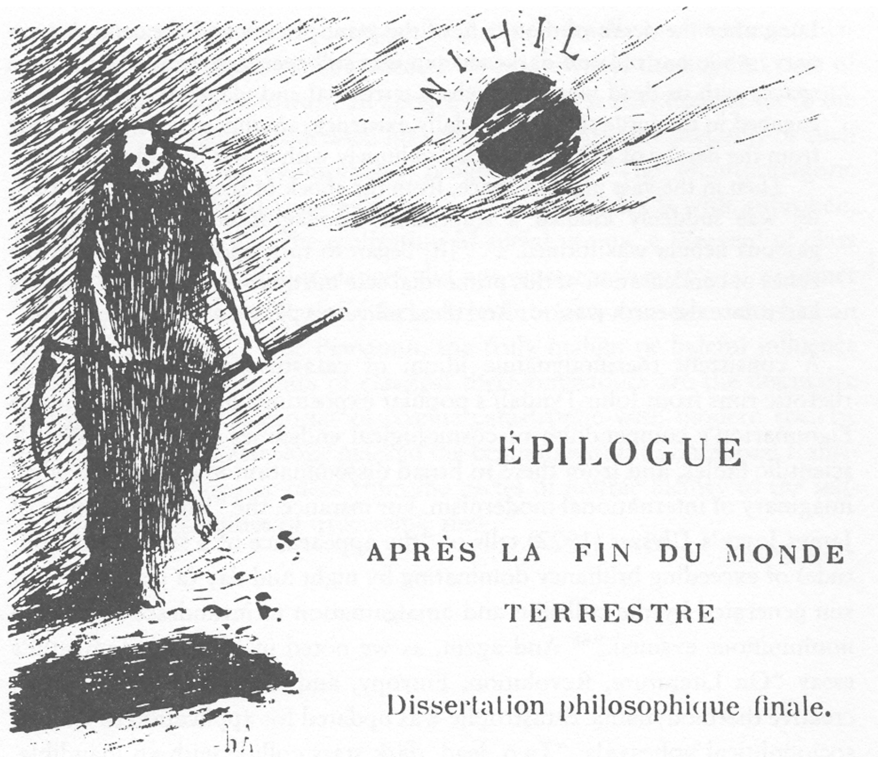

Figure 4.1: Title page from the scientist and author Nicolas Camille Flammarion's *science fiction novel La Fin du Monde, from 1893. Although the novel is about the end of the world caused by a comet colliding with the Earth, the black sun with the 'nihil' above it, reminds the reader of the thermodynamic version of the end of the world. (Source: Clarke 2001).*

Thomson may have been well aware of the implications of his article. And though his audience might not have understood the scientific details, they would be inclined to accept the overall storyline that he laid out in his article.

Thomson's article on the sun's heat has an inverted cause and effect structure, which emphasises the theoretical foundation of the text. Thomson sets out to explain that the world will end at a certain time because of the convertibility of energy (i.e. entropy), which means that everything at some point in the past was highly unstable. This notion of instability is one of the keys in his theory and also plays a big part in the article. Thomson writes: "It is also impossible to conceive either the beginning or the continuance of life, without an overruling creative power; and, therefore, no conclusions of dynamical science regarding the future condition of the earth can be held to give dispiriting views".[6] Here Thomson puts science in the place of a form of divine power and as the primary force in his story: He first outlines how it will all end, then goes on to state the present situation and lastly discusses the origin. In this way, Thomson constructs a narrative, which shows progress not in an ordinary linear sense, but rather in an inverted sense showing the effects before the cause.

[6] Thomson 1891, p. 357.

Thomson's choice of this particular line of argumentation mirrors the theoretical foundation of his text, namely the second law of thermodynamics. The effects of the second law of thermodynamic are in this respect far more important than the causes, because it will result in the end of the world, as we know it. Thus, the narrative Thomson presents, consists of a complete narrative about the world, and he presents to his audience a new worldview based primarily on thermodynamics and secondly on science. Thus, the analogies with the presentations by evolutionary theorists are striking. In any case, Thomson also presents a worldview that challenged religious beliefs in the sense that the thermodynamic version of the end of the world is a scientific alternative to the biblical apocalypse.

As discussed previously, in order to present a certain worldview, a certain type of authoritative stance towards one's audience is required. Throughout the text, Thomson continues to address his audience in an authoritative voice. For instance, he writes: "How much the sun is actually cooled from year to year, if at all, we have no means of ascertaining or scarcely even of estimating in the roughest manner".[7] The 'we' here refers to the scientific community; or more specifically the community that came up with the theory on the sun's heat and who knows how it works. Although Thomson does not speak of solid facts,[8] but rather estimates and probabilities, he still speaks with authority and hence there is no doubt left that the sun loses heat. Thomson does not use a construction of the audience that would integrate them with the author as 'we', as for instance T. H. Huxley does in his article on chalk. Instead, Thomson has an authoritative stance with his audience: "It would extend this article to too great a length, and would require something of mathematical calculation, to explain fully the principles", he writes.[9] The voice of authority here tells the audience that there is further information they do not need to know, and thus takes up the role of selecting what should be disclosed to the audience. Hence, Thomson's narrator and the readers are not exclusively on a quest together on equal terms. And the narrator thus can have two different roles in the text and be both (alternatively) on the side of the readers and of the scientific community.

"On the Age of the Sun's Heat" is an excellent example of how a particularly scientific worldview can be communicated successfully to an audience. Thomson's narrator has the same characteristics as were seen in the texts on evolutionary theory: The authoritative voice of the narrator helps convince the audience of the truth-value of thermodynamics, though, as Thomson himself points out, the theory is just a theory. It is possible to view Thomson's article as a classic example of a nineteenth-century popular science text as characterised by the field of literature and science. A reading of Thomson's article with emphasis on the literary influence furthermore indicates that the writings within different scientific disciplines and theories were very similar in many ways: A story needed to be

[7]Thomson 1891, p. 358.

[8]Mainly because at the time scientists did not have the means to perform experiments that could confirm that the sun loses heat.

[9]Thomson 1891, p. 373.

conveyed to an audience at a time when science and literature shared similar views of the world. However, as we move closer into the field of thermodynamics, characteristics different to those of evolutionary theory emerge.

4.3 Maxwell, Demons and Dynamics

As was the case with THOMSON's article, there are many elements in MAXWELL's scientific writings that fit with both the Darwin-case and the analytical model constructed from it. In this respect, I have chosen to focus on one central element in one of MAXWELL's texts, namely MAXWELL's Demon, which is intimately connected to his use of storyline, character, narrator and style. MAXWELL's Demon may well be one of the most interesting literary characters of science in the Victorian Period. Additionally, the Demon prompted a particular style that contributed to the literary quality of MAXWELL's writings. In the writings on literature and science, MAXWELL's Demon is often mentioned, but a thorough analysis of the Demon as a literary component has, to the best of my knowledge, not yet been undertaken. In the following, I suggest how the Demon can be seen as a productive way of analysing the relations between science and literature in the context of thermodynamics.

One might say that MAXWELL in some ways was the first to make physics an abstract science as regards the way he sought to verify his theories. MAXWELL is probably best known for his work on electromagnetism,[10] where one of his contributions was the positing of a mechanical model to prove his theories. He used this method repeatedly, but after he had devised his equations of electromagnetism he came to realise that he did not actually need the mechanical models, because everything could be explained either through abstract thought experiments or equations. Furthermore, there are actually many different ways in which you can construct and structure a mechanical model whereas you only need one equation (see *Figure 4.2*).[11] MAXWELL's Demon is precisely such an abstract thought experiment, and thus shows how an abstract construction can render part of a specific theory understandable.

Thought experiments have been used throughout history, but the scientific usage of thought experiments did not became widely used until the fifteenth century. GALILEI GALILEO (1564–1642) was probably the first scientist to use though experiment. His famous proof that falling objects must fall at the same rate regardless of their mass was actually not physically carried out by throwing various objects from the Leaning Tower of Pisa, but was a thought experiment.[12] The thought experiments can be seen in contrast to

[10]Most often, MAXWELL's work on electromagnetism is related to his equations. These showed that light can be thought of as electromagnetic waves by describing the properties of the electric and magnetic fields (Harman 1998, p. 103).

[11]Bowler and Morus 2005, pp. 93–95.

[12]Bowler and Morus 2005, pp. 42–43.

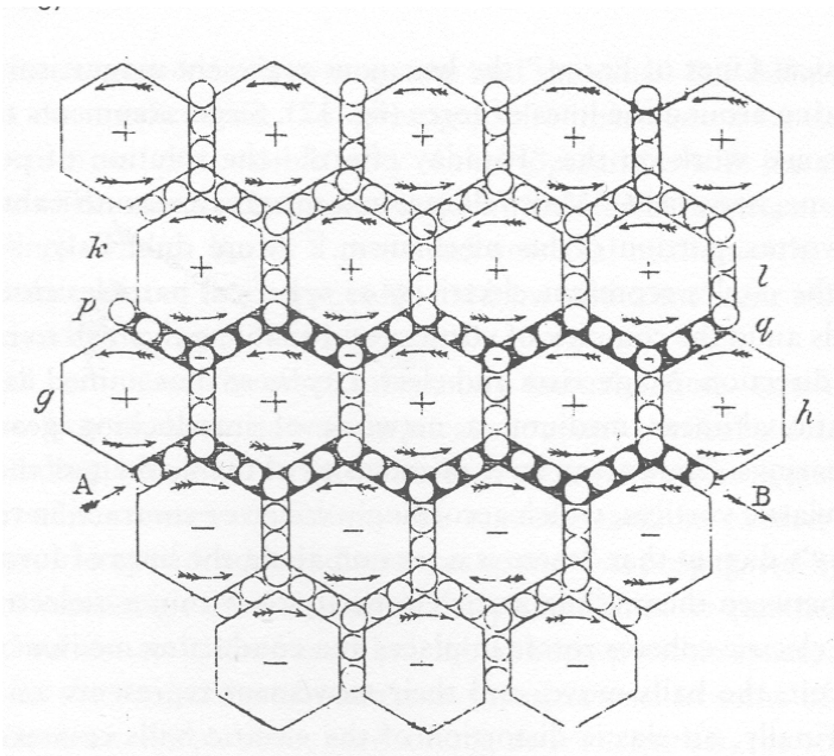

Figure 4.2: MAXWELL's *ether model from his "On Physical Lines of Force", 1861.* MAXWELL *constructed this electromagnetic ether in order to investigate the interrelation of electricity and magnetism. But as* BRUCE CLARKE *puts it: "Maxwell considered the ether substance as factual fiction — convinced of its existence in some form, he was sceptical about any particular description of it, including his own" (Clarke 2001, p. 100). (Source: Harman 1998).*

concrete experiments, because the thought experiments can easily be conveyed through illustrations, graphs, etc., and in some ways, it speaks for itself.[13]

But the thought experiments can also be seen in contrast to pure speculation, because they imply that a concrete experiment can be carried out physically. In this respect, the thought experiments are essentially concrete experiments that tell rather than show — that is, the thought experiments rely on language rather than concrete physical experiments. In this respect, the literary quality of the thought experiment is stronger than in for instance an experiment, because the scientist is able to construct and manipulate his experiment through language rather than scientific instruments. Furthermore, since the nature of the thought experiment is linguistic, the experiment relies purely on language as disseminator and not for instance scientific instruments. When writing about or setting up a thought experiment, the scientist will be forced to consider how he narrates his experiment, as we shall see with MAXWELL's Demon. Despite the differences between the different kinds of expressions of the experiments, the premises for the thought experiments are more or less the same as with an ordinary experiment, which also is the case of MAXWELL's Demon.

[13]Dennett 1995, pp. 180–182.

In his *Theory of Heat*, Maxwell introduces a 'being', a demon, in his discussion on the kinetic theory of gases that deals with how molecules move within a gaseous body. The reason Maxwell needs to construct a being is to make clear a hypothetical way to manoeuvre around the second law of thermodynamics. What Maxwell wants is to try and set up a scenario where heat does not always flow from warmer to colder bodies. In order to do this, Maxwell needs to be able to handle the molecules individually and thereby be able to move heat from colder to warmer bodies and thereby violate the second law of thermodynamics.[14] Maxwell introduces his being and writes on the second law that:

> [I]t [the second law of thermodynamics] is undoubtedly true as long as we can deal with bodies only in mass, and have no power of perceiving or handling the separate molecules of which they are made up. But if we conceive a being whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are still as essentially finite as our own, would be able to do what is at present impossible to us.[15]

Maxwell's being is thus basically a molecule-sorting demon that is finite like humans, but much more skilled and can work under certain speculative conditions. Maxwell thus has a hypothesis concerning the second law of thermodynamics and uses the Demon as a counter-argument against the second law. This contra factual construction shows the limitation of the second law and the Demon-construction assists Maxwell in his argumentation. Thereby, the Demon is part of Maxwell's argument, without being part of his theory as such.

Although some theorists have interpreted the Demon in a religious way because the word 'demon' derives from the word for supernatural, Maxwell's Demon is more profitably to be viewed as a being that is above or beyond our world and not as such as a religious one. However, as the historian of science Graeme Gooday argues, the Demon might have: "[S]urmised how an angelic counterpart might have acted instantly to direct molecular motions throughout the cosmos in ways beyond the facility or comprehension of human agents".[16] In my view, this is exactly the point of Maxwell's Demon: Since we are neither able to comprehend nor experimentally prove how to dismantle the second law of thermodynamics, Maxwell uses the Demon as an agent. In the end, Maxwell thus created a fictitious being in order to explain his scientific theory.

The demon-character also bears other implications, Laura Otis writes: "Maxwell's 'demon' is a creature of imagination having certain perfectly well-defined powers of action, purely mechanical in their character, invented to help us understand the 'Dissipation of Energy' in nature".[17] Though the Demon might be somewhat mechanical in his nature (there are many things he cannot do, but he is able to move molecules in any direction), he is still a character essential to the thought experiment and the thesis that Maxwell

[14] Harman 1998, pp. 138–140.
[15] Otis 2002, p. 72.
[16] Gooday 2004, p. 133.
[17] Otis 2002, pp. 79–80.

lays out. As Otis writes, the Demon is also a tool to help the reader interpret Maxwell's theory, or narrative, correctly. And thus the Demon both functions as an inevitable part of an experiment and as a facilitator in the text itself. Maxwell's demon therefore plays a far more vital role than the characters we saw exemplified in the texts on evolutionary theory. They merely supported the narratives but were not necessary for the theories to be realised.

In many ways, there are similarities between the way in which Maxwell and Darwin, and to a lesser degree Thomson and Huxley, communicate their theories and arguments. Both Darwin and Maxwell had to communicate complicated theories that were dependent on a particular outlook of the world: Darwin needed to sell the theory that the Earth and its species had evolved, and Maxwell had to explain the aspects of the thermodynamic laws in a context where the heat death was present. Maxwell and Darwin used extensive literary tropes as fundamental parts of their works. Likewise, character, storyline and narrator are important parts of all four scientists' writings. Though the similarities are striking in many ways, I would argue that although Maxwell's Demon also fits within the framework of the analytical model, it is also here that the case of thermodynamics begins to separate itself from the Darwin-case. Although Darwin (and Huxley for that matter) uses certain characters in *Origin* he could have replaced them by other characters or tropes and the overall theory of evolution would not have suffered. The Demon is indispensable for Maxwell's argumentation. The Demon is much more than a device to enhance a particular scientist's argumentation; it *is* an argumentation on its own. In this way, Maxwell's language and use of literary devices, in the case of the Demon, are active parts of the theory and not just a reader-friendly way of communicating a difficult scientific theory.

4.4 Maxwell as a Literary Writer

The fact that Maxwell more actively uses literary elements as part of his theory opens up to new perspectives in analysing the interrelations between literature and science. Further perspectives emerge when looking into the differences between the Darwin-case and the case of thermodynamics, because Maxwell, himself, presents views on the relations between science and literature. These views have, to the best of my knowledge, not been dealt with by writers within the field of literature and science who have instead concentrated their efforts on studying allegories rather than analogies. This is unfortunate since Maxwell's writings on analogies provide a key to understanding his interpretations of the relationship between literature and science. These views can be found in Maxwell's article "Are There Real Analogies in Nature", which he wrote in 1856, years before he introduced his Demon. The article mainly describes the nature of scientific analogies but also incorporates thoughts on literature. Maxwell begins his text with references to a cultural and linguistic context rather than a scientific, pointing out the fundamental difference between a pun and an analogy. A pun, according to MAXWELL, is two expressions hidden under one expression whilst an analogy is one truth, which can be uncovered behind two expressions. Thus, according to MAXWELL, analogies have to do with the relationship between two linguistic agents but which have the ability to reveal a secret beneath.[18]

The fact that MAXWELL starts his article by referring not to science but rather to culture corresponds well with his view of popular science and the importance of science for culture in general. MAXWELL writes:

> [W]e are daily receiving fresh proofs that the popularisation of scientific doctrines is producing as great an alteration in the mental state of society as the material applications of science are effecting in its outward life [...] If society is thus prepared to receive all kinds of scientific doctrines, it is our part to provide for the diffusion and cultivation, not only of true scientific principles, but of spirit of sound criticism, founded on an examination of the evidences on which statements apparently scientific depend.[19]

This quotation shows how MAXWELL was very conscious about the role science was beginning to play in society, including how science was becoming increasingly important both to the public in general and to the arts faculties. Science and scientific method could not be overlooked when it came to methodology. These realisations also had an influence on MAXWELL's work on language, tropes and science.

The core of MAXWELL's view of analogy is that every trope is an analogy: "[T]he question is entirely of their reality",[20] MAXWELL writes. Hence, MAXWELL emphasises a literary language as the basis of a scientific text. But MAXWELL takes his view on literary aspects further than a mere linguistic construction. MAXWELL initially poses the question of whether analogies are real and exist in nature or are merely constructions. MAXWELL discusses objects in the world and writes:

> Before we can count any number of things we must pick them out of the universe and give each of them a fictitious unity by definition. Until we have done this, the universe of sense is neither one nor many, but indefinite. But yet, do what we will, nature seems to have a certain horror of partition. Perhaps the most natural thing to count 'one' for is a man or human being, but yet it is very difficult to do so.[21]

He continues:

> For we have no reason to believe, on the ground of a given succession of simple sensations, that differences in position, as well as in order of occurrence, exist among the causes of these sensations. But yet we are convinced of the coexistence of different objects at the same time, and of the identity of the same object at different times.[22]

[18]Maxwell 1990, p. 376.
[19]Quoted in Goldman 1983, p. 183.
[20]Maxwell 1990, p. 376.
[21]Maxwell 1990, p. 377.
[22]Maxwell 1990, p. 377.

In these two quotations, it becomes apparent that Maxwell argues for the human construction of all objects (even abstract ones including numbers). Humans thus create fictitious unities in order to come to grips with the universe, and it is in the way in which we position objects in relation to each other that we interpret them. In the end, Maxwell displays an understanding of the way in which language (and tropes) works, but he is also aware of the connections between language and objects in nature. Maxwell thus makes clear how science is connected to language on a grammatical level but also in connection with narration.

Maxwell's view on science can be seen in relation to some of his other texts. I will therefore return to Maxwell's Demon and how one can connect the Demon to Maxwell's view on language and in particular analogies. On a narrative level one can view the Demon as an analogy. In Maxwell's *Theory on Heat*, he sets out to test the second law of thermodynamics by introducing the Demon. Thus, Maxwell operates with two scenarios; one where the second law of thermodynamics applies and where entropy eventually will imply the still-stand of everything, and one where a being can manipulate molecules so that the second law can be broken. Both cases are narrative analogies that both support the argumentations of his thermodynamic theory. The fundamental thermodynamic theory (or the fundamental storyline, which we may also call it for the purpose of this argument) is of course in the end what Maxwell would argue for. Both the Demon and the absence of the Demon will support thermodynamic theory. For even though the Demon prevents entropy, which is fundamental for thermodynamic theory, the thought experiment dismantling the second law is still part of the thermodynamic body of theories. Thus, Maxwell uses the second law of thermodynamics and his Demon as an analogy, two expressions under which lies the truth of thermodynamic theory. Thereby, he also illustrates the fact that the thermodynamic storyline is the correct theory on the development and end of the world.

Maxwell not only employs his views on the literary qualities of science in connection with his Demon. In Maxwell's lecture "Molecules", written a couple of years after his introduction of the Demon, he sets out to define the molecule. It was in this lecture that Maxwell defined the molecule as: "[T]he smallest possible portion of a particular substance".[23] Maxwell was the first to define the word 'molecule' in this context and with it molecular science dealing basically with something that was then still invisible, which presented him (and indeed many other scientists at the time) with the problem of examining the molecules. In his lecture, Maxwell presents the thermodynamic thesis concerning molecules, namely that the movements of molecules in gases and liquids are caused by surrounding air and other gases. At that period in time, this was not possible to prove easily since molecules could not be seen in microscopes. And even though Maxwell refers to many experiments designed to prove this aspect of thermodynamic theory, even the existence of molecules could not be proven experimentally. Hence, Maxwell's molecules exist

[23]Maxwell 1873, p. 437.

as a linguistic construction in the text before they could be said to exist in nature. Since it could not be proven experimentally that molecules existed, MAXWELL states towards the end of his lecture:

> Thus we have been led, along a strictly scientific path, very near to the point at which Science must stop. Not that Science is debarred from studying the internal mechanism of a molecule which she cannot take to pieces, any more than from investigating an organism which she cannot put together. But in tracing back the history of matter Science is arrested when she assures herself, on the one hand, that the molecule has been made, and on the other that it has not been made by any of the processes we call natural.[24]

This quotation points back to an ambivalence that is also found in connection with the Demon. The molecule may in this respect only be a 'fictitious' creation and not a natural phenomenon. Thus, like in the case of the Demon, there are two contradictory statements (a natural and fictitious phenomenon, respectively) that both are necessary argumentative devices in order to support his theory. The molecule becomes MAXWELL's constructed analogy of an invisible world that may or may not exist in the state that MAXWELL claims. Hence, through his text on analogies in nature, MAXWELL shows that both as scientific text and theory and as literary text, he can control his language and scientific argumentation when it comes to the narrative and to the individual tropes corresponding to his views on science and literature.

As illustrated with the above articles, it is visible that many aspects of the thermodynamic texts fit well with how scholars in the field of literature and science approach scientific texts. In fact, one might argue that the field would benefit greatly from using elements of MAXWELL's thoughts on language and the construction of scientific language. The few existing works on MAXWELL and thermodynamic texts have more or less dealt with the thermodynamic storylines and individual tropes of the writings, mostly metonymies and allegories, despite the fact that MAXWELL wrote on analogies as already discussed.

However, MAXWELL's thoughts on language and science have not, to the best of my knowledge, been actively explored in the analyses of thermodynamic theory, which may be due to the dominance of the Darwin-case in the field in a nineteenth-century context. With the rising interest in thermodynamic theory (and indeed other scientific theories of the nineteenth century) scholarship within the field can no longer only focus on the same aspects that were central to the case of DARWIN. MAXWELL and the case of thermodynamics will be able to bring out new aspects of the relationship between Victorian science and literature. Moreover, the case seems likely to bring forth new analytical practises within the field of literature and science.

[24] Maxwell 1873, p. 441.

4.5 Textual Thermodynamics

In the field of literature and science, it has been common to read thermodynamic texts more or less in the same ways as the texts by Darwin and other evolutionary theorists. As in the case of Darwin, it has been the literary critics who began to take an interest in Maxwell and thermodynamics, concentrating their analyses around specific tropes and narrative structures. If we briefly return to some of the fundamental conflicts that are present within the field of literature and science, many historians of science writing within the field have objected to the notion of science as primarily a (linguistic) construction. The somewhat deconstructivist approach employed by literary critics like Beer and George Levine can seem out of place when we take Maxwell's view on science and language into consideration. I believe that in due time, these readings will undoubtedly meet with the same criticism (or counter analyses) from the historians of science in the field as in the case of Darwin. My point here is not to diminish the criticism made against the methods of certain writers within the field of literature and science. Instead, I wish to point out that although the analyses focusing on science as language to some extent do not take all aspects of scientific writings into consideration; scientists like Maxwell were conscious of the role of language in science. Thus, an analysis with focus on science as a linguistic construction may be more justified (historically) in the case of Maxwell than in the case of Darwin.

The uniqueness of Maxwell's thought experiment and his thoughts on science and language present us with the opportunity to investigate not only his scientific thesis and thermodynamic principles but also his narrative and the ways in which language constructed his argumentation. If one takes Maxwell's own view of the scientific text into consideration this could bring forth new perspectives on how nineteenth-century scientific texts can be interpreted. Maxwell's thoughts on literature and science may open up towards new analyses in the field of science and literature that will differ from the analyses in the case of Darwin and evolutionary theory.

4.6 Maxwell and New Perspectives on Literature and Science

From some of the texts by the scientists involved with thermodynamics, it is evident that it is possible to employ the analytical model of the Darwin-case with only minor adjustments. Almost everything carries over, although it may be necessary to look into other tropes than were important in the Darwin-case. Just as I have, writers in the field of literature and science (both literary critics and historians of science) have used Darwin as a point of reference and based their analyses upon his works. Hence, the works by Darwin naturally fit in with the methods applied by the writers in the field. As illustrated, texts by thermodynamic theorists may successfully be interpreted according to the same methods applied to the case of Darwin, although Maxwell's texts in particular demand a change in focus. Many of Maxwell's popular science texts fit in well with very textual analytical approaches like a deconstructivist readings, but a reading emphasising the autonomy of science is also possible:

Maxwell himself opens up for textual analyses in his works but at the same time he is conscious of the fact that science has more than one dimension. In the quotation on the role of science in society (see p. 96), Maxwell mentions that science exists as an entity designed to describe and investigate the physical world, but at the same time its methods and features have an influence on culture and society. Hence, science as a linguistic construction is only one element of Maxwell's view on science and language. Science may also be seen as an autonomous system whose methods influence its surroundings. Thus, there is also room for analyses of Maxwell and thermodynamic texts that are not exclusively based on textual approaches.

One of the key discussions fashioned by this chapter is whether the conflicts of the field that are visible from the works on Darwin and evolutionary theory will also prevail in the case of thermodynamics. In the end, I would argue that the field of literature and science would benefit from using Maxwell's thoughts on literature and science as a whole. Maxwell presents us with a unique view of his scientific language and the construction of texts, which could contribute new perspectives to the conflicts within field of literature and science, perspectives that do not naturally arise when studying the case of Darwin and evolutionary theory.

Chapter Five

Conclusion

> "In fact a favourite problem of [Tyndall] is — Given the molecular forces in a mutton chop, deduce Hamlet or Faust therefrom. He is confident that the Physics of the Future will solve this easily."
>
> T. H. Huxley in a letter to Herbert Spencer, 1861

In this dissertation, I have studied how the scientists of the nineteenth century have used literary elements and literary structures in their scientific writings. Through the past decades, a substantial number of literary critics and historians of science have taken an interest in the scientific writings of the nineteenth century, focusing on the mutual influences between literature and science. In this respect, the writers of this field of literature and science have investigated how the scientific writings could be analysed in a literary context, usually based on constructivist theories of both literary criticism and the history of science. Using the works written on Charles Darwin and his works' relation to literature as the basis of this dissertation, I have constructed an analytical model that would also serve as a general textual model for nineteenth-century scientific writings. The analytical model considers the nineteenth-century context, with particular emphasis on the narrator, storyline, style and the language and tropes. Included in the analytical model are also reflections about the basic conflict that is present within the field of literature and science, represented by the different views by literary critics and the historians of science, respectively.

The fact that the Darwin-case has dominated the views on science and literature in a nineteenth-century context has had a substantial influence on the way in which other scientific theories of the period are and have been interpreted. Only in recent years, an increasing number of works on thermodynamic theory has begun to emerge and shown new ways of looking at the relations between nineteenth-century science and literature. It was my initial assumption that the analytical model constructed on the basis of the Darwin-case, with minor adjustments, would fit in with the case of thermodynamics. Naturally, there are obvious similarities on the contextual level between the two cases — for instance the circumstances surrounding scientific practices in the Victorian age. On the other hand, certain tropes, linguistic constructions and narratives are important only in individual cases. Hence, it is not unexpected that the works on thermodynamics have been inspired by the Darwin-case, with emphasis on the tropes used in the writings of thermodynamics.

However, the case of thermodynamics and in particular the works of JAMES CLERK MAXWELL presented new perspective beyond the analytical model. Looking at DARWIN and especially *Origin*, there can be no doubt that DARWIN was conscious of his language and how he communicated his theory of evolution. However, the metaphors, analogies, etc., which DARWIN employed in his texts were, albeit well-executed, only illustrations of his arguments, not indispensable. For instance, when DARWIN compares an ant colony to human society, the comparison illustrates his argument, but he could have chosen another analogy and the argument would not have suffered. The same goes for his more complicated metaphors, for instance the metaphor of natural selection, where one might imagine other metaphors for describing that nature evolves because of particular biological circumstances. Hence, although DARWIN's texts are rich and filled with literary grandeur, his theory is not dependent on this (although the success of the *Origin* and the evolutionary theory probably were). The texts by MAXWELL, as I see them, differ from this aspect in a fundamental way: MAXWELL puts our understanding of the relations between nineteenth-century literature and science into a new perspective, because he himself displays an awareness of the language and the literary elements, which we do not find in for instance DARWIN's works.

MAXWELL's Demon is not just a randomly chosen literary figure; it plays a vital role in MAXWELL's work. Contrary to DARWIN, MAXWELL does not have a theory that can be illustrated only by pointing out specific features in nature or similarities between human society and nature; MAXWELL has to construct a thought experiment that can assist him in his argumentation. This notion can also be seen in relation to MAXWELL's writings on analogies, because, according to MAXWELL, the analogies do not only exist as concrete entities in nature, they also exist as linguistic figures in scientific texts. Hence, MAXWELL's take on text and the construction of texts is best compared to the post-modern literary theories like structuralism and deconstructivism, which is characterised by questioning the basic reality and texts and thereby, it fits very well in with the approaches employed in the field of literature and science.

In the end, we are left with the question of why MAXWELL has not been 'discovered' or at least been paid more attention to by the field before? I do not think that MAXWELL and other nineteenth-century scientists have been deliberately ignored by the field of literature and science. Rather, I believe that DARWIN and the story that DARWIN tells is the key to an answer to this question. DARWIN's works quickly achieved fame after they were published, and not only because of the scientific qualities of the works, but also because of the literary qualities. DARWIN, in a sense, wrote the story about us, the human race. Thus, it was not only a scientific narrative, but *the* grand narrative, which DARWIN wrote. And DARWIN's narrative is still one of the grand narratives about us, which is why he is still popular today and will probably remain being so. And thus, even though Maxwell (and probably also other scientists) could bring forth new perspectives that could be used in the analyses of the relations between literature and science, they have remained in the shadow of Darwin and his narrative. Maxwell and the other theorists of thermodynamics may have told the story about how the world would end, but this story is not nearly as powerful as the story about the human race.

The Field of Literature and Science — From Then to Now ...

I will now briefly return to the introduction of this dissertation, where I reflected on the possibility of a unified and interdisciplinary theory of literature and science. I am still convinced that a truly interdisciplinary theory will most likely not be possible to establish because the differences not only in the outlook on science but also the differences in the nature of the theories of the history of science and literary criticism will make a unified theory highly improbable. However, I do believe that Maxwell presents new perspectives on the connections between literature and science, which may assist the field of literature and science in moving forward, especially in the context of nineteenth-century scientific writings.

The key is to bring forth some of Maxwell's views on science in relation to literature and thereby get away from some of the fixed notions based on the numerous readings of Darwin. By doing this, I believe it would be easier to reach consensus between the historians of science and literary critics within the field, because Maxwell presents a nuanced picture of the nature of science. To Maxwell, science is not a linguistic and literary construction, like the position of some literary critics, but science is not totally independent of language either, according to Maxwell. Maxwell's view of analogies thus shows how science is the link, or the interpreter, between nature and language, where, in both cases, the analogies exist as concrete entities. Thus, I believe that writers within the field of literature and science would benefit from studying Maxwell's person and scientific writings (although these are a lot more difficult to decipher than for instance those of Darwin) in greater detail and employ his view of science and literature in contrast to Darwin and indeed other nineteenth-century scientists, in order to further bridge the conflict between the two sections of the field.

It is not my claim that Maxwell is the sole solution to the fundamental conflict of the field of literature and science, or that Maxwell's view on science and literature is the way to reach a grand unifying theory on the relationship between literature and science. But Maxwell can bring forth new perspectives on how nineteenth-century scientific text could be viewed in central aspects. A concrete way of employing Maxwell's view of science is to use his view in an analysis of other scientific writings: Thus, one could accept the premise that no trope or literary figure is indispensable for the argumentation of a particular scientific text. That is, if we assume, like Maxwell, that there is a close connection between science as a discipline, nature and language, we would be able to construct an analytical frame that would include all of these aspects. Naturally, we cannot assume that every scientist is as conscious of the construction of his text as Maxwell was, but a 'Maxwellian' analysis of the text could disclose more about the relationship between text, science and the field that the particular scientists are interested in.

... and in the Future

Finally, we may take a brief look at the future of the field of literature and science. Whether belonging to the literary section or the history of science section within the field, the analyses carried out are to some extent founded on literary analyses. But the literary methods are being threatened today for instance by the movement of Literary Darwinism, which is based solely on biological and sociobiological methods of analysis and thereby rejects the post-modernist theories of the history of literature.[1] As of now, the Literary Darwinists have mostly looked into how the canonical works in literary history revolve around basic human biological features. In the future, the Literary Darwinism Movement will probably begin to take an interest in literature's influences upon science.

The Literary Darwinists are thus beginning to challenge the methods and approaches held by the writers within the field of literature and science by having rejected the post-modern theories of literature. As stated above, by considering new perspectives on the relation between science and literature from a scientist like Maxwell, the fundamental conflict of the field of literature and science will perhaps not be as dominating in future works, which, in the end, will strengthen the field in relation to for instance the Literary Darwinism Movement. A revision, or at least a modification, of our understanding of the relation between nineteenth-century literature and science might keep the field of literature moving, and through the eyes and pens of the writers within the field, new relations between science and literature may emerge.

As a final conclusive remark, I might draw the attention to the title of this dissertation, *In Midstream*, which of course points to the fact that the study of the relations between literature and science is somewhere between two independent fields of research. Furthermore, it seems that many of the scientists of the nineteenth century also were located somewhere midstream between a growing tradition within the professional sciences, moving the scientific texts towards a more technical and particular style, and a surpassed tradition of writing scientific text in a more literary style. By looking into the studies of nineteenth-century scientific texts as well as the field of literature and science itself, it has been a challenge to navigate between the two banks of the stream, but it has indeed opened up for new perspectives on both the field and on the texts that are all in-between.

[1] See footnote 17 in Chapter Two, p. 22.

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Index of names

Abstract: Dansk

Siden begyndelsen af 1980erne har både videnskabshistorikere og litteraturteoretikere i stigende grad interesseret sig for samspillet og den gensidige påvirkning mellem litteraturen og naturvidenskaben. Afhandlingen "Vadestedet — Litterære strukturer i videnskabelige tekster i 1800-tallet" fokuserer specifikt på den side af emnet om litteraturen og naturvidenskaben som handler om, hvordan litteraturen har indflydelse på naturvidenskabelige tekster. Afhandlingens cases er centreret om 1800-tallets naturvidenskabelige tekster, især med fokus på evolutionsteorien og Charles Darwins værker samt termodynamikken og James Clerk Maxwells tekster.

Læsninger af Darwins værker i relation til litterære påvirkninger og elementer har igennem de sidste godt 30 år været med til at sætte standarder for, hvordan både litteraturteoretikere og videnskabshistorikere har tolket litteraturens indflydelse på naturvidenskaben på. Det er endnu ikke lykkedes at etablere en teori, der forener de videnskabshistoriske og litteraturteoretiske praksiser til fulde. Manglen på en egentlig forenende teori har derfor også betydet, at de fleste videnskabshistorikere, der skriver om emnet litteratur og videnskab, har gjort og stadig gør brug af videnskabshistoriske metoder, blandt andet retoriske analyser og konstruktivistiske analyser. Ligeledes har litteraturteoretikere gjort brug af især postmoderne teorier, blandt andet strukturalismen, med fokus på sproget som styrende for videnskaben, som baggrund for deres læsninger af emnet litteratur og videnskab.

Samtidig har de mange læsninger af Darwins tekster været skueplads for en grundlæggende konflikt mellem visse litteraturteoretikere på den ene side og visse videnskabshistorikere på den anden side. Konfliktens omdrejningspunkt er blandt andet synet på naturvidenskaben: Mange litteraturteoretikere hævder, at naturvidenskaben er skabt af sproget og litterære elementer. Modsat mener videnskabshistorikerne ikke, at sproget danner eller er styrende for videnskaben. Denne grundlæggende konflikt er således en uomgængelig del af de mange læsninger af naturvidenskabelige tekster og vil derfor indgå som en del af afhandlingens analyse af værkerne skrevet om 1800-tallets naturvidenskabelige tekster.

Afhandlingen er bygget op omkring en læsning af udvalgte evolutionsteoretiske tekster samt en analyse af de forskellige tolkninger af disse. Herudfra struktureres en tekstanalytisk model, som kan lægges til grund for analyser af andre 1800-tals naturvidenskabelige tekster. Den analytiske model bliver herefter sammenlignet med og diskuteres i lyset af termodynamiske tekster, især med fokus på Maxwells tekster, for at afgøre hvorvidt den analytiske model kan opfattes som en generel model, som kan anvendes på de fleste videnskabelige tekster i perioden eller om teksterne af Maxwell bringe nye perspektiver på banen, der vil revidere den analytiske model. Diskussionen af Maxwells rolle i forhold til samspillet mellem videnskaben og litteraturen vil også indbefatte en diskussion af de metoder og den konflikt, der er en uomgængelig del af analyserne af 1800-tallets naturvidenskabelige tekstproduktion.

Abstract: English

Since the beginning of the 1980s, an increasing number of literary critics and historians of science has taken an interest in the connections between and mutual influences of literature and the natural sciences. The dissertation "In Midstream — Literary Structures in Nineteenth-Century Scientific Writings" focuses on the subject of how literature has an influence on scientific texts. The case studies of the dissertation are centred on nineteenth-century scientific writings, especially with a focus on evolutionary theory and the works of CHARLES DARWIN as well as the works of thermodynamics and texts by JAMES CLERK MAXWELL.

During the past thirty years, readings of the DARWIN'S works have set standards for how both historians of science and literary critics have analysed nineteenth-century scientific texts. As of yet, no theory has been established to unify the methods of literary criticism and the history of science. The lack of such a unifying theory has meant that most of the historians of science, who write on the subject of literature and science, employ methods of the history of science — amongst which rhetorical analyses and constructivist analyses. Likewise, the literary critics have often made use of literary theories, especially postmodern theories, amongst other structuralism, with emphasis on language basis of science, as background for their readings of subject of literature of science.

Furthermore, the many different readings of the works by DARWIN have made way for a conflict between certain literary critics on the one hand, and certain historians of science on the other. The central notion of the conflict involves the view of science: Many literary critics claim that language and literary elements constitute science. Contrary to this view, most historians of science hold that science is not controlled or for that matter created by language and literature. The basic conflict between the theorists of literature and science is inevitable when dealing with the many readings of the scientific texts, and therefore the conflict will be considered in the analysis in the dissertation of the works written on the nineteenth-century scientific texts.

The dissertation is constructed around a reading of selected texts on evolutionary theory and an analysis of the different interpretation of these texts. From this point an analytical model is established. The analytical model will be the basis of the analyses of other nineteenth-century scientific texts and will be compared and discussed in relation to the case of thermodynamics. The discussion will especially will be centred on the texts

by Maxwell, in order to establish whether the analytical model can be seen as a general model that can be employed on any nineteenth-century scientific text, or whether the case of Maxwell brings about additional perspectives that aspire to develop or modify the model. The discussion of Maxwell's role in relation to the connection between literature and science will also include a discussion of the methods and the conflict that is an innate part of the analyses of the nineteenth-century scientific writings.

MAXWELL with wife KATHERINE and dog, 1869.

DARWIN on his horse Tommy, 1868.

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