Popular and Academic Genres of Science: A Comparison, with Suggestions for Pedagogical Applications

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2001

Submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Linguistics in the Faculty of Human Sciences, University of Natal, Durban

Abstract

This thesis reports on a comparison of four genres of scientific writing: the research article, university textbook, popular science article and science books for children. The comparison is based on a functional linguistic analysis of what are taken to be exemplary texts from these genres and focuses on the levels of register (or context of situation), genre (or context of culture) and ideology (loosely used to mean power relations reflected in and achieved through discourse). The textbooks and research article examined are found to be similar in register but distinct at the level of genre. Allowing for the difference in age of the readers, the study also finds broad similarity between textbooks and science books for children at both the levels of register and genre. Differences between popular science texts and the other three genres are particularly marked at the interpersonal level, and can be explained in terms of the popular science texts in the study being primarily news genres. Specifically, two of the popular texts in the study are issues reports (characterised by White 1997 as 'the discoveries of some authorised source'), while one is an opinion piece.

The basis of the examination of ideological differences between the four genres is from the perspective of how each genre establishes objectivity, what each regards as constituting a fact, and power relations between reader and writer. Research science achieves objectivity by universalising propositions by removing association with people, time and place (Latour and Woolgar 1979). The research article functions to persuade readers (who represent the powerful research community) to accept knowledge claims (Myers 1989). This persuasion must be accomplished through an appearance of objectivity through removal of human participants and without the more usual interpersonal devices such as attitudinal lexis. Propositions become fact when they are accepted, and cited as uncontroversial by the research community.

Like the research article, textbooks appear objective by removal of association with people. However, by contrast with research articles, writers of textbooks are more powerful than their readers are. Textbook writers, in summarising all information accepted as fact by the research community, are representative and mouthpiece of that

powerful community. In privileging facts (scientists' ideas) over scientists themselves, textbooks extend the power differential noted by Myers (1989) between research community and individual researcher. Textbooks reify the fact and further bury the individual, containing only generic references to scientists. Science books for children, like textbooks, contain only generic references to scientists. They do, however, try to engage readers through illustrations and by identifying readers with scientists.

Popular science texts are distinct from the other three genres in establishing writer objectivity through the journalistic means of attributing ideas and utterances to authoritative human participants in the text. Popular texts, because they report on findings that the research community has not yet endorsed as fact, are distinct from research articles and textbooks in representing findings as provisional and even controversial, and thus provide an insight into science as a social activity that is absent from the other genres.

This research finds little evidence that popular science represents a simpler or more accessible form than textbooks. Indeed the similarity in register and genre between textbooks and science books for children calls into question the commonly-held conception of factual texts as inherently more difficult than forms such as narrative. This research indicates that research articles and textbooks are target forms for tertiary students and students in the later years of secondary school. Motivated by this, the researcher suggests that importing features of popular science writing into textbooks would be counter-productive. Instead she suggests a greater role for popular science texts themselves at secondary and at tertiary level. In providing an insight into scientists as people and the social nature of how facts are established, popular science texts can go some way to dispelling the mystique of science as authoritative and difficult.

Acknowledgements

I would like to thank my supervisor, Ralph Adendorff, for his guidance in the planning of the research described in this thesis, and for his perceptive advice throughout the writing of the thesis.

Secondly, I thank Dr Nicole Geslin, Prof. Keith Chick and Prof. Nancy Hornberger for their valuable insights and advice. I am also grateful to the Linguistics department of the University of Natal, Durban for the opportunity to contribute to their Language and Power course, as this has been of benefit in refining my own thinking.

Finally, I am grateful to my husband and children for their patience and encouragement.

Unless specifically indicated to the contrary in the text, this thesis is my own original work. It has not been submitted for a degree to any other university.

Jean Parkinson

TABLE OF CONTENTS

TABLES OF FIGURES

Tables and Figures in Chapter 1

Tables and Figures in Chapter 3

Tables in Chapter 4

Tables in Chapter 4.1: A research article: Raup and Sepkoski

Tables in Chapter 4.2: The textbook genre: an analysis of an extract from a first year Geology textbook, including comparisons with a textbook for advanced students and a textbook for non-scientists.

Tables in Chapter 4.3: A popular science journal: the Scientific American article

Tables in Chapter 4.4: A Newspaper article: the Mail and Guardian extract

Tables in Chapter 4.5: Four books for children

Tables in Chapter 4.6: Comparison of genres analysed in this chapter

Tables in Chapter 5

CHAPTER 1 INTRODUCTION

1.1 The value of studying popular science genres

Science has become more influential than religion as a source of authority in western culture in modern times. In 1859 Darwin attempted to increase the credibility of his theory of evolution by arguing that it was not at odds with a biblical view. Nowadays proponents of the biblical view of creation give this view credibility by renaming it "creation science". The authority of science in western culture does not however imply wide understanding of most scientific concepts by most people. In spite of this, such is the authority of science that most western people accept a scientific view on most issues.

A current example in South Africa is the controversy about what causes AIDS. Scientific authorities, such as the South African Medical Research Council, claim that HIV causes AIDS. They support their assertion with research studies that indicate that use of anti-retroviral drugs controls the onset of AIDS in HIV positive patients. This view has the overwhelming support of the newspapers in South Africa, and, on the evidence of their letters pages, of their readers too. This is in spite of the fact that very few people outside of the medical profession have a sophisticated understanding of how viruses interact with the body, or what an immune response is. The authority of science alone is enough to convince most people that the solution proposed by medical science and reported in the newspapers is reliable. It is worth noting however, that the so-called 'AIDS dissidents', who claim that HIV does not cause AIDS, also stress the scientific basis for their viewpoint, indicating that science is authoritative for people on both sides of this controversy.

The limited understanding most people have of most scientific topics is perhaps inevitable given the newness, complexity, and amount of scientific knowledge. Our access to scientific knowledge is also limited. Besides what we learn at home and at school, newspapers and other popular sources such as television and magazines are our main sources of scientific knowledge. This makes popular science articles a central source of knowledge about science for most people. Popular science articles in newspapers, newsmagazines and also in popular science journals have a far larger readership than most research articles, but little research has been done into the discourse features of popular science genres. In the chapters that follow I consider the discourse features and ideological assumptions of popular forms (including popular news articles and science books for children) and compare these to the academic genres that have been the subject of greater enquiry in the past. I consider too the extent to which popular forms can be usefully used in the classroom.

1.2 Research questions

In any study, it is useful to have a standard against which to measure the phenomenon under focus. Because they have been widely studied, and because much is known about their discourse features, academic genres such as research articles and textbooks are the obvious choice for comparison with popular genres. My enquiry thus focuses on how popular genres deviate from these well-studied genres, which are also widely acknowledged to be important and influential. This comparison is reflected in my first research question:

1. *What distinguishes popular scientific genres from academic ones, and how do they relate to each other?*

Furthermore, some research (e.g. Myers 1989) has also been done on power relations in research articles, giving me some yardstick against which to measure the ideological assumptions of the popular texts in my study. This concern is reflected in my second research question:

2. *How does register in representative texts from each genre illuminate the ideological assumptions of each genre?*

Since my initial motive for starting the study on which I report in this thesis was to get an insight into the pedagogical appropriateness of using popular articles to teach science writing, this is the subject of enquiry of my third question, namely:

3. *What is the pedagogical relevance of an understanding of questions 1 and 2 to science teaching?*

These questions give shape to what follows, a matter that I return to in section 1.5 below.

1.3 Influences on my study: its focus and methodological orientation.

As my three research questions above suggest, this thesis reports on a comparison of the discourse features of scientific texts in four genres, seeks to illuminate the ideological assumptions of the texts studied, and by extension the four genres, and considers the pedagogical relevance of an understanding of these features. Two of the four genres that I concentrate on - research article and textbook – are 'serious' genres of science and have been relatively well studied (e.g. by Bazerman, 1988, Myers, 1989, 1992b, and Martin, 1993). The other two genres – articles in magazines/ newspapers, and children's books – are popular genres of science and have been the subject of considerably less research, e.g. by Myers (1991) and Fahnestock (1986). Thus a starting point for this study is a comparison of the popular with the more serious genres. To accomplish this comparison, representative texts from each genre are examined in depth, using Systemic Functional Grammar (see below).

This comparison of popular and academic scientific genres is prompted firstly by recent work in linguistics on the interpersonal dimension of scientific discourse. Myers (1989:28) for example, in a study of reader-writer relations in research articles, suggests that the relationship between reader and writer is likely to be a simpler one in popularisations than in research articles, a suggestion not entirely borne out by the present study. Fahnestock (1986) suggests that popularisations are far less likely to hedge knowledge claims than are the research articles from which they are drawn. Once again this is a suggestion not entirely supported by the findings of this study. Investigation in the field of the sociology of science into the nature of scientific facts in research science (e.g. Latour and Woolgar 1979; Knorr-Cetina 1981) indicates that the discourse of science is ideologically informed. Chapter 4 will show a somewhat different orientation in popular texts to facts and to establishing objectivity compared to research articles. These suggestions indicate that a fuller comparison of popular with academic scientific texts – with particular emphasis on realisation of the interpersonal metafunction - will prove useful in illuminating the ideological dimension of these genres. In fact, as this thesis shows, there are distinct differences in power relations between reader, writer and research community in each of the genres that constitute this study.

I am stimulated secondly by work by Lemke (1990) to seek ways of making easier the learning of science, and in particular the learning of scientific literacy. As a teacher of science writing (at tertiary level), I was prompted to explore whether the popular science texts I give my students are suitable models for learning how to write academic scientific discourse. My choice of popular texts is partly motivated by the fact that my students are second language speakers of English and have also attended under-resourced schools and are thus regarded by the university as "under-prepared" for science study. I therefore choose popular texts for their somewhat easier content level and what I assume to be their greater accessibility. However, if those texts differ too greatly from academic science texts, either grammatically or ideologically, the advantage of greater accessibility of content is negated. This is a matter I report on in chapter 5.3.

My decision to include science books for children as a genre worthy of study was prompted by a number of studies on genre, focusing on textbooks in particular, by Australian Systemic Functional Linguists. In particular, the claim by Martin (1989) that factual genres are not more difficult than narrative, merely less familiar, prompted me to consider books for children as a genre other than textbooks. Books for children, moreover, are a genre that is read for pleasure, rather than for the instrumental reasons that motivate readers of textbooks. My discussion in section 4.5 as well as that in chapter 5 will show that, while shedding light on the discourse features of children's science books and their similarity to textbooks, my study offers no answer to the question of the relative difficulty of factual genres.

However, this investigation does have some application for science education generally. Textbooks and other science materials are sometimes said (e.g. by Lemke 1990, and Sutton 1996) to be dry and impersonal. As news genres, popular science texts can by contrast be expected to be more engaging of the reader. An investigation into popular texts is therefore useful in deciding whether the elements in popular texts that make them more engaging can be used in materials for school children. The research also sheds light on the extent to which science books for children are similar to and prepare children for academic texts. This is an important issue on which, to my knowledge, little or no research has as yet been done.

Methodologically my study employs Systemic Functional Grammar in an attempt to provide a systematic and comprehensive comparison of the grammatical features of five texts that I selected as representing the four genres in the study. I was prompted to employ Systemic Functional Grammar as a tool in my analysis by its promise of explaining, in terms of the grammatical choices made by the writer of the text, how a text makes the meanings it does. Because of its focus on meaning Systemic Functional Grammar enables an examination of ideological meaning. It allows the analyst to base his/her judgement of ideological meaning in the text not on intuition or on the distribution of a few grammatical items (such as use of modality or of the passive voice) but on a comprehensive framework of grammatical features that can be systematically compared across the texts analysed. This framework of grammatical features is considered along three dimensions of meaning: ideational or content meaning, interpersonal meaning (the relationship between reader, writer and how they feel about the content), and organisational or textual meaning. These three dimensions enable a comprehensive description of a text at the level of register. Such description is also useful to the analyst in comparing texts at the levels of genre and of ideology. Martin (1992: 405) makes the analogy between the meaning made at the levels of register, genre and ideology and the layers of an onion. This analogy, illustrated in Figure 1, usefully stresses the layered nature of Systemic Functional analysis, and the way, for example, that the level of Ideology includes but also goes beyond the levels of genre and register. I provide a fuller account of this framework in chapter 3.

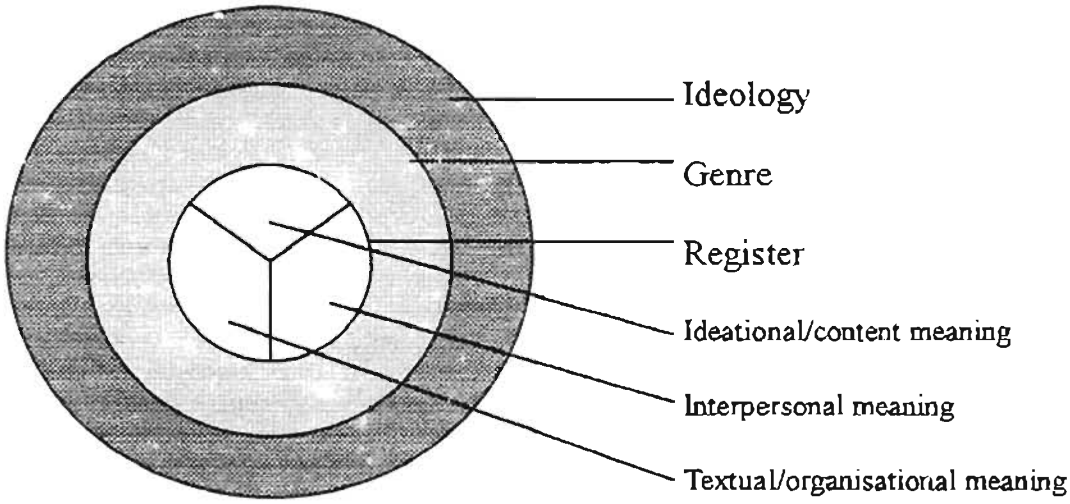


Figure 1: The levels of Register, Genre and Ideology in the Systemic Functional Model (adapted from Butt, Fahey, Spinks and Yallop, 1995)

1.4 Texts analysed for this study

A representative text from each of four genres – the research article, the textbook, the newspaper article and the science book for children - was chosen for analysis. (A full account of these texts is provided in section 3.1). The texts chosen are all on the same topic, for the purpose of keeping the ideational meaning as similar across texts as possible. The topic chosen was: what caused the extinction of the dinosaurs. The selection of this topic was motivated by a wish to select a topic of current popularity in a number of genres in the study: research articles, popular journal articles and science books for children. Reflecting a new area of enquiry in research, the extinction of the dinosaurs was an extremely popular topic in popular science journals such as New Scientist and Scientific American between 1980 and 1995. For example in this period no fewer than 60 articles were published on the topic in the New Scientist alone. Dinosaurs continue to be a popular topic for children's science books; feature films such as *Jurassic Park* and television documentaries such as the BBC *Walking with Dinosaurs* are an indication of their enduring fascination for adults as well.

A number of texts on the topic in each of the four genres was collected: ten research articles, four textbooks, about 70 popular articles and ten science books for children. This collection of texts was then narrowed down and a limited selection was fully analysed. Between one and four texts were analysed in each of the four genres, but for reasons of economy, a single typical text was chosen as an example of each genre, with reference and comparison made to other texts in the genre:

Table 1.1: Texts in my study

Genre	**Number of texts originally considered**	**Number of texts analysed**	**Number of texts considered in Chapter 4**
Research article	10	1	1
Textbook	4	3	1, with additional reference to 2 further texts
Popular article	70	3	2, with additional reference to 1 further text
Science for children	10	4	1, with additional reference to a further 3 texts

As popular texts fall into a wide range of genres, and as a wider range of audiences are addressed by popular than by academic texts, two texts from this genre are fully analysed in chapter 4 rather than a single one. Nevertheless, this study does not pretend to provide a comprehensive survey of popular or academic science genres. Breadth of survey has been sacrificed for the sake of depth. Two written popular news genres – the issue report and the opinion piece - are examined in the study. To limit the length of the study, the following popular science genres have been omitted:

- Longer articles in popular science journals such as Scientific American, in which a researcher or sometimes a journalist expands on a particular piece/area of research. This long science article is less common than the short science articles (generally issues reports) found in newspapers, newsmagazines as well as popular science journals.
- Genres such as television nature documentaries or news documentaries on a current topic in science are omitted in order to keep the length of the study reasonable.

In terms of academic genres, a single textbook genre, the information report, is included, and no attempt is made to examine a fuller range of textbook genres.

1.5 An overview of the structure of this thesis

Chapter 2, the survey of relevant literature, and chapter 3, which provides a brief outline of Systemic Functional Grammar as an analytical tool, provide the background against which the analysis of texts takes place in chapter 4 of this thesis. Chapter 4 suggests answers to my first two research questions:

1. *What distinguishes popular scientific genres from academic ones, and how do they relate to each other?*

2. *How does register in representative texts from each genre illuminate the ideological assumptions of each genre?*

Chapter 5, a consideration of the pedagogical applications of the findings in chapter 4, concerns the third of my research questions:

3. *What is the pedagogical relevance of an understanding of questions 1 and 2 to science teaching?*

To expand on the above, in chapter 2 I survey a number of bodies of literature that have influenced me in my analysis. I begin my account by discussing several concepts that are centrally important in my analysis. These include the concepts of discourse, literacy, register, genre and ideology. As indicated in 1.3 above, Systemic Functional Grammar enables analysis of texts at the level of register, which in turn is useful in analysis at the levels of genre and ideology because it provides essential information about organisation of the text, participants in the text, and the relationships between participants. All three of these terms (register, genre and ideology) have been used with some range of meaning in the literature. I therefore reflect on how these terms have been used, and explain how I use them in this study. The term genre, for example, has a 'large-scale' meaning (examples are research articles and textbooks) and a 'small-scale' meaning (examples are explanation and procedure) as developed by Australian workers on genre theory. Both are useful to me in this study, and I use the term in both ways. Similarly, ideology has been used with the neutral meaning of 'beliefs or values', as well as more negatively, to denote meaning that functions to sustain power relations. Once again, I use both meanings in my study. Chapter 2 also surveys studies that have been done of science genres such as research article, textbook and popular science article.

As mentioned earlier, Chapter 3 provides a detailed account of the texts analysed in chapter 4. Chapter 3 also provides a brief and simplified description of how Systemic Functional Grammar analyses register. In doing so it gives a fuller account than that provided in 1.3 of the dimensions of meaning at the level of register: ideational, interpersonal and textual meaning, key elements of the framework for analysis used in chapter 4. It considers these different components of meaning in language from the point of view of texts as well as of illustrations. A framework for analysis of meaning in illustrations is necessary, because, as reflected in the copies of texts in the appendix, all texts in my study are accompanied by illustrations.

Chapter 4 is the central chapter of the thesis, and constitutes about half the length of the thesis. This chapter provides answers to the first and second of my research questions. It constitutes an analysis and comparison of the four different genres that are the subject of this thesis. Chapter 4 is long because it provides an in-depth analysis of register, genre and ideology in five texts, regarded by me as exemplary of the genres they represent. The length is also partly accounted for because of the extensive comparison between texts that is fundamental to my study, and by the numerous tables necessary in an analysis of this sort, where a close to statistical portrait of the discourse features of each text is attempted.

Chapter 4 is organised into six sub-chapters:

- 4.1 reports on my analysis of an extract from a research article.
- 4.2 reports on my analysis of an extract from a first year geology textbook, making comparison with two other textbooks: an extract from a textbook for advanced students, and an extract from a textbook for non-science students.
- 4.3 reports on my analysis of a popular science article from Scientific American, and compares it with an extract from a further popular article from Time magazine. Both of these are examples of news articles of the issues report genre.
- 4.4 reports on my analysis of an extract from a further popular genre, an opinion piece drawn from a South African newspaper, the Mail and Guardian.
- 4.5 reports on my analysis of an extract from a book for children, Prehistoric Life, and compares this to three other science books for children.
- Finally, 4.6 summarises and compares the four genres analysed in sub-chapters 4.1 to 4.5.

Each of these six sub-chapters follows the same pattern of organisation, reflecting the necessity in this study for systematic comparison of features across texts. Each sub-chapter analyses the same features in its elucidation of register. These are:

- Ideational meaning (Field). I consider human participants, processes and participants, and circumstances.
- Textual meaning (Mode). I consider theme, nominalisation, passivisation, and conjunctive relations
- Interpersonal meaning (Tenor). I consider contact, affect and status, hedging and evaluation.

Each sub-chapter then proceeds to discuss the levels of Genre and Ideology. My reference to ideology in each of the six sub-chapters considers how objectivity is established in each text in the study, and what each genre considers to constitute a fact. It considers the power relations between reader, writer and research community in each genre.

Chapter 5 is where I consider the third and last of my research questions, the pedagogical implications of the analysis of register, genre and ideology in chapter 4. This chapter is more suggestive than chapter 4. I examine the extent to which the research article and textbook are target forms for students. I then reflect on the advantages and disadvantages

to students of using popular texts in learning scientific literacy. I consider also the value of use of popular science texts by teachers of science, and reflect on whether importing aspects of popular writing into textbooks would have any value or not. Finally I examine the extent to which science texts for children are similar to textbooks, and may thus be a preparation for using textbooks in later life.
In the appendix I provide a copy of the original of each text in the study together with a further copy of each text divided into numbered clauses. The appendix has been organised so that the copy of the original text folds out beyond the right margin of the page for ease of reference while reading chapter 4.

In chapter 6 I conclude this thesis by briefly summarising the main findings of my research, considering the limitations of the study and suggesting possibilities for future research.

CHAPTER 2 LITERATURE SURVEY

2.1 Introduction

In this chapter I summarise literature from several fields that has influenced me in my study, and which informs the analysis on which I report in chapter 4. These fields include Systemic Functional Linguistics including work done in this tradition on science, news, and on genre; the New Literacy Studies; the New Rhetoric Studies, including work in this tradition on science and on genre; and finally, research on ideology, including the perspective on ideology of Critical Language Study. This body of literature provides essential insights both in my analysis of scientific genres and in the answers I offer to my three research questions (cf. section 1.2). In section 2.2 of this chapter I outline and distinguish between two concepts that are central to this study: *literacy* and *discourse*. These terms have been used with some variation in the literature, and it is therefore important to clarify my use of them in this study. In section 2.3 I provide some theoretical background to the field of Systemic Functional Linguistics, which is central in the study in that I use it in chapter 4 as a first step in analysis of the texts I consider. (Chapter 3 provides a brief explanation of the grammar of Systemic Functional Linguistics from a more methodological perspective.) To complete my analysis in chapter 4 a consideration of genre, register and ideology is necessary, and these concepts I define in sections 2.3.1, 2.3.2, and 2.3.3.

Since my study focuses on a comparison of popular with academic science genres, I therefore, in section 2.5, survey the work that has been done on the different science genres in the study (research article, textbook, popular science and science for children), and point to its relevance to my own study. As science popularisations appear in newspapers and news magazines, they can be considered to be news discourse. I therefore look briefly (in section 2.6) at research that has been done on News, particularly work in the tradition of Systemic Functional Linguistics (where, usefully for my purposes, considering my research questions, emphasis has been both on genre and on ideology).

2.2 Literacy and discourse

The concept of literacy has been revisited by Street (1984, 1993), Heath (1986) and others. Traditional definitions of literacy concern being able to read and write (Goody 1968). However Heath's (1986) study of three communities indicates the very different literacy practices of different communities, the different values placed on text by different communities and the different ways that children are socialised into literacy. For Heath literacy is therefore more complex than being able to read and write. It includes (1986:98) the different "interpretive processes and strategies" used by a community. This has been extended by the New Literacy Studies (Street 1993), which view literacy practices as not only closely related to and reinforced by community values and beliefs (Adendorff 1999:56), but also "imbued with ideology" (Street and Street 1991:143). My research seeks to identify distinguishing discoursal features of exemplary texts in the four genres of science writing studied, and through an understanding of them to illuminate the ideological assumptions of the texts under investigation. In particular, I am interested in the possibility that ideological differences between popular and academic texts may make popular texts a useful addition to science teaching.

Heath's (1986) work indicates that how we use text is culture-dependent, and that different groups have different literacies: different "ways of taking" meaning from text, different sets of practices and values associated with speaking, reading, writing. My study focuses specifically on the discourse of science, and examines a plurality of literacies/communicative practices in texts in a range of genres in science. Texts I consider include articles on science from newspapers, news magazines and popular science magazines as well as mainstream academic literacies, for example research articles and textbooks. An approach that views literacy as plural rather than a simple matter of being able to read and write is of use to me in this study because of my interest in how the acquisition of academic literacies can be facilitated. As I indicate in chapter 5, I teach a scientific writing course in which I make use of popular science texts because of their somewhat easier level of content. However if the communicative demands of reading and writing a popular text are very different from those of reading and writing more academic texts, then the use of popular texts in the teaching of academic science writing may not be advantageous to students.

Gee's (1990) use of the term 'Discourse' is similar to the above use of the term literacy. He distinguishes his (capitalised) use of the term from the more general way 'discourse' is used in linguistics to mean 'language produced as an act of communication' (Richards, Platt and Platt, 1992:111). As with 'literacy', Gee's use of Discourse involves the combination of reading, writing and speaking with action, thought and feeling. For Gee (1990:175) being a "member of a Discourse" involves not only using language but also sharing the values, ideas and emotions of the Discourse and behaving in a way regarded as appropriate by members of the Discourse. One must be able to take on a role recognised by others members of the Discourse. As Gee points out, this makes a Discourse more difficult to teach/acquire than we would otherwise expect, because in order to acquire the Discourse one must become acculturated into it in order to play the role convincingly. To become a member of the Discourse of science a student thus needs to participate in and regard as natural and self-evident the values of research science, for example, that science should be quantitative, repeatable and free from bias.

2.3 Systemic Functional Linguistics

This thesis reports on discourse analysis, as mentioned earlier, of a number of genres in science. As a first step in the discourse analysis process, namely to analyse and describe the texts and thus enable them to be compared, I employ Systemic Functional Grammar, making it the central analytical tool in the analysis. In chapter 3 I focus on how Systemic Functional Grammar analyses text, outlining the categories in the grammar, and how these are identified. In what follows by contrast, I provide a brief theoretical background to Systemic Functional Linguistics, the view it takes of language and text, and the ways in which I consider it particularly useful to my analysis

Halliday (1994:xiii) indicates that Systemic Functional Grammar is functional in that it tries to 'account for how the language is used'. Systemic Functional Grammar views meaning in text as reflected in three metafunctions: the ideational (which fulfils the purpose of language of understanding the environment), the interpersonal (which fulfils the speaker's purpose in allowing him/her to act on others and indicate attitude), and the textual (which organises the message). Systemic Functional Linguistics is built on a view of language as a system of options. For example the choice between question and statement, between different lexical items, or between expressing what we say in a series of short clauses linked by conjunctions or a series of long clauses with extended nominal groups as described in the comparison of spoken and written language above. Systemic Functional Grammar thus provides a very useful tool for analysing text at the level of the clause, while building up a systematic and even statistical impression of how language has been used to construct the message of the text. Analysing the choices that the writer has made enables the reader to draw conclusions about how the writer views the world, the relationship between writer and reader etc. In short it is important for this study because of the insights it affords about the writer's ideology, the concern of my second research question (cf. section 1.2). Although time-consuming and difficult to employ for long texts, Systemic Functional Grammar affords the analyst a fair degree of certainty about the correctness of the analysis because the same features are systematically and comprehensively considered for different texts, allowing a statistical insight into grammatical differences between texts.

Like Firth, Halliday views the text rather than the sentence as central to analysis of language. For Halliday (1994:xxii) a 'theory of the system' of language is only useful if it can 'account for how the system engenders text'. Similarly, we cannot understand a text unless we understand the system. Halliday (1994:xxvii) draws a distinction between structural grammars (which are syntagmatic, having 'structure as their main organising feature and bringing in special devices to relate one structure to another') and Systemic Functional Grammar which is paradigmatic. This means that in Systemic Functional Grammar 'the description of any feature *is* its relationship to everything else'. The benefits of this conception of grammar can be seen in chapter 4 in my analysis of use of the passive, of nominalisation, and of human participants in the texts in my study. The passive as well as nominalisation are used extensively in research articles and textbooks to omit human participants as agents. This has an influence on the thematic progression of the texts as the goal rather than the agent is in first/thematic position more often than expected. Thus a choice which appears to function at the ideational level (who the participants in the text are) has important functions too at the interpersonal level (omitted agents to create the impression of objectivity) as well as the textual level (the apparently marked choice of goal as theme).

Analysis of a text affords us an understanding of 'how, and why, the text means what it does' (Halliday 1994:xv). Beyond understanding a text, if we wish to evaluate the effectiveness of the text, we need to take account of its context. Halliday (1994:xvi) indicates that the analysis of the meaning of a text must be related to context at two levels: the context of situation and the context of culture. Both derive from Firth, (1957:144), who suggests that we can arrive at an understanding of language if we use data from contexts that are 'typical, recurrent and repeatedly observable'. Whether this refers to recurring genres (such as research articles or prayers) or recurring speech situations (such as classroom interaction, church services etc.) is not entirely clear from this. In Halliday's (1994:xxxi) conception the context of situation of a text is its environment, while the context of culture is the environment of the overall language system.

Martin (1992:495) equates context of situation with register, which comprises three components, Field, Tenor and Mode (Martin, 1992:404). These correspond to the ideational, interpersonal and textual metafunctions. Martin (1992:495) furthermore equates context of culture with genre (see section 2.3.1 below), an interpretation of genre I follow in this study. To the levels of genre and register Martin (1992:405) adds ideology as a third layer of meaning. I discuss genre, register and ideology in the following three sections, viz. 2.3.1, 2.3.2 and 2.3.3.

2.3.1 Genre

Discussion of the concept of 'Genre' is particularly rich in the literature and very useful for my purposes in this study since genre is the primary category in terms of which selection of texts was made. Texts within the four genres I analyse in this study (research article, textbook, popular science article and science books for children) are indeed in Firth's words (1957:144), 'recurrent and repeatedly observable'. Distinctions between these genres are universally recognised by users of the texts

Hyon (1996) notes that there are three traditions in the study of genre: English for Specific Purposes (ESP), Australian theories of genre, and the New Rhetoric Studies in the United States. ESP and Australian work on genre has, according to Hyon (1996) stressed the structural features of genres. The New Rhetoric studies by contrast have stressed the contexts in which genres occur and what they are used to accomplish. For example, in the ESP tradition, structural move analysis has been used to analyse the organisation of research article introductions (Swales 1981). In the Australian studies there has also been explicit identification of obligatory and optional structural elements of a genre. For example Butt, Fahey, Spinks and Yallop (1995:17) identify narrative, recount, information report, discussion, explanation, exposition and procedure as genres. This stress on structural elements reflects the strong pedagogical emphasis in both ESP and the Australian studies. Both have analysed the structural elements of genre for the purpose of facilitating the learning of genres. ESP has applied such work at tertiary level in specific fields such as science, commerce and law, and work on genre in Australia has had wide application at school level. Nevertheless, in both traditions, it is not merely structural elements of genre that are important. Rather, there is recognition that the social context of genre is important. For example in the ESP tradition, Swales (1990:58), defines genre as 'a class of communicative events which share some set of *communicative purposes which are recognised by the expert members of the parent discourse community*'. Similarly, in the Australian tradition Martin (1984:25) defines genre as 'a staged, goal-oriented purposeful activity in which speakers engage *as members of (their) culture*'.

In relation to science the communicative purpose of the research article, for instance, is universally recognised by research scientists as getting research findings recognised by the discourse community. We can view research scientists as members of a culture of science (or in Gee's (1990) terms, members of a Discourse), in that they share certain values and behave in such a way (linguistically and otherwise) as to be recognised as scientists by other members of the culture. As will be seen below, this notion of shared values within a culture of science has importance for my second research question, concerning ideology. It is because scientists share values that they subscribe to a particular belief system and accept the power relations within the science discourse community. This in turn, as I explain below (in 2.3.3.4), is reflected in the characteristic grammatical features of scientific discourse.

By contrast with ESP and the Australian studies, the New Rhetoric studies place far less stress on knowledge of surface features of a genre (Hyon 1996:699). This approach focuses less for example on use of the past tense passive in the Method section of a research article, and pays more attention to the motive for writing a Method section impersonally and why this section of a research article is formulated as it is. Miller (1984:159) considers genres to be "typified rhetorical actions based on recurrent situations". 'Action' in the context of this tradition refers to the social purposes that a genre fulfils. Bazerman (1988:323) for example, stresses the need to "understand the fundamental assumptions and aims of the community", making the values and goals of the community primary, and showing less attention to the structural features. He (1988:153ff) also illustrates the dynamic and changing nature of genres and warns against representing them as structurally or linguistically static. He illustrates this point by looking at changes in structural and grammatical features in a journal, the *Physical Review*, over a period of 90 years. He shows, for example, how articles emphasised methods and research instruments at the beginning of the period but, in response to rapid development of knowledge in the field, by the end of the period, emphasis was on theoretical concerns. An example of change at the grammatical level is the doubling in proportion of noun clauses (presenting facts, claims or observations – I refer to them as 'fact clauses' in chapter 4) in the articles over the 90 years studied (Bazerman 1988:168).

These different definitions of genre have led to the labelling of texts of different sizes as genres. Bazerman (1988), for example, working within the New Rhetoric tradition, refers to the research article genre (a key genre in my investigation) Although emphasis in the Australian genre studies has been on textbooks (for example Martin 1993, Wignell, Martin and Eggins 1993, Veel 1997), and more lately on media genres (White 1997), an analysis of the research article in this tradition would, I imagine, see a number of genres within the research article. These would include the recount genre in the method section of a research article and exposition, explanation or discussion in the Discussion section of a research article etc. In this study I use the word in two main ways. Firstly I use the term genre in the broad sense as Bazerman (1988) has used it and speak of four different genres to be analysed in this study. This view of genre is useful to me firstly because the genres are universally recognised as such by their users, and secondly because I view the genres in my study as a whole (e.g. research article), as fulfilling the writer's purpose, not the subsections within the genre (e.g. method section). For pedagogical purposes however, the Australian approach is very useful. Therefore in chapter 5 and in the sections on genre in chapter 4, I focus on the staged nature of smaller scale pieces of text that would be regarded as distinct genres in the Australian tradition.

In summary, from the discussion in this and the previous section, it is clear that there is some overlap in the use of the terms literacy (as used in the New Literacy studies), Discourse, and genre (particularly as used in the New Rhetoric studies, but also present in Martin's (1984) reference to 'culture' and Swales's (1990) reference to recognition by the discourse community). In its broadest definition, a literacy involves use of language and associated behaviour and conceptualisations within a cultural context. To this, in his use of the term Discourse, Gee (1990) adds values, emotions and the ability to take on an appropriate role. (This is particularly useful to me in considering my second research question, which concerns the ideological assumptions of the genres I study). The term 'genre' has similar meanings to Discourse with regard to the assumptions and aims of the community but studies of genre have focused to a greater extent than do studies of literacy or discourse on typified forms with identifiable structural features.

2.3.2 Register

In sociolinguistics the term register is used to mean "sets of language items associated with discrete occupations or social groups" (Wardhaugh 1998:48). In Systemic Functional Linguistics however, the term has a wider meaning and is used by Halliday (1989:44) to mean functional variation: variation in language according to the functions it is being used for. Halliday elsewhere (1993:54) defines register as "a cluster of features having a greater than random tendency to co-occur". He views scientific English, for instance, as a register and points out (1993:54) that, like a dialect with which we are familiar, we recognise the register of scientific English when we see it. This implies that a number of different scientific genres fall into this category of scientific register. Elsewhere however, Halliday (1985:318) lists "narrative, transactional, and expository" texts as examples of registers, indicating some overlap with Australian genre studies' concept of genre. By contrast Martin (1992:469) (who I follow in this thesis) distinguishes register from genre, characterising register as forming a level below that of genre and above that of semantics (which in turn is above the level of grammar).

Focusing now on what it is about scientific writing that makes us recognise it as a distinct register, Halliday (1993:56) suggests that a text is recognised as "scientific English" because of the combined effect of "clusters of features" and, importantly, the relations of these features throughout the text These features include nominalisation of verbs and adjectives, technical terms, extended nominal groups, tentative language, causal and reasoning verbs, and impersonal language and passivisation. These features, especially nominalisation, tentative language, passivisation and impersonal language are central to my analysis in chapter 4. They are discussed at greater length in sections 3.2.3 and 3.2.5.

With respect to these clusters of features in science texts, Lemke's (1990) study of classroom discourse indicates that these may have an important influence on the ease with which children learn science. For example, Lemke (1990:22) suggests that learning science is difficult for those from social backgrounds where the preferred grammar, rhetorical patterns, figures of speech and activity structures of science are unfamiliar (for example, impersonal passivised writing). This has some relevance to my discussion in chapter 5, where I consider the relevance to teaching science and scientific writing of differences between the four genres analysed in my study.

As indicated in section 2.3 above, register comprises three components: Field, Tenor and Mode, corresponding to the ideational, interpersonal and textual metafunctions. I discuss these metafunctions in greater depth in chapter 3, but as they form the basis of my analysis in chapter 4 I will provide a very brief sketch of them here. Field refers to meaning in the sense of content (Halliday 1994:106), and refers to the experiential function of language. Focus on field involves who or what the participants are, and what they are doing, thinking or being and associated circumstances (how/when/where etc) Tenor refers to the interaction between speaker/writer and listener/reader. Scientific writing is unusual in using attitudinal lexis (commonly used in non-science texts to express interpersonal meaning) only very sparingly, and relationship between writer and reader is reflected in subtle elements such as modality and evaluation. This omission of attitudinal lexis from science writing is related to the western cultural association of attitude with subjectivity, and the need in academic scientific writing to be objective. Mode, the third component of register, refers to how a text is organised. Mode concerns how a clause fits in with the rest of the message, forming a coherent whole by making links to clauses ahead of it and before it in the message by the use of such devices as thematisation and conjunction.

In chapter 4 I analyse register (or context of situation) in four genres (research article, textbook, popular article and science for children), and this forms the basis of my analysis of two other levels of context: genre (context of culture) and ideology. Having considered the use of the terms genre and register above, I turn, in the next section, to consider some of the literature associated with the concept of ideology.

2.3.3 Ideology

The popular conception of science, and one shared by many scientists, is that science is objective, and its discourse thus very little influenced by the subjective beliefs of individual scientists. However, it is well established amongst sociologists of science (e.g. Latour and Woolgar 1979, Knorr-Cetina 1981) that the appearance of objectivity is carefully constructed by the use of grammatical conventions in the discourse of science. In order to increase the likelihood that readers will accept their ideas, writers must employ the conventions signalling objectivity to increase the credibility of the discourse in the minds of the readers. This does not imply that scientific discourse is largely untrue, or an attempt to deceive readers: the writers believe and have evidence for what they write. Nevertheless they must follow the conventions of objectivity in what they write in order to persuade readers to accept their findings. If their findings are accepted by the scientific discourse community (primarily researchers working in the same field but also the wider scientific community who take an interest in the findings), writers attain power in the form of prestige, funding etc. This makes scientific writing highly persuasive in intent and points to objectivity as part of an ideology of science. As will be seen in Chapter 4, objectivity is achieved differently in different genres. The ideology of objectivity is part of what gives science authority in the wider societal context, and scientific findings and facts are used by those with political and economic power to justify policy decisions. This has important implications for my second research question, which concerns the ideological assumptions of the genres I examine.

In this section I review the range of meanings associated with the term ideology. I consider how power is exercised through discourse, which is the vehicle for the expression of ideology. As power is used to control access to resources, I consider what resources are at stake in science discourse, both within the science discourse community and in the wider context of society. I then take a closer look at the power relations within a variety of science genres: research articles, textbooks and news articles. I consider finally how authority is established in science and how a proposition comes to be accepted as fact. The notion of authority is central to the exercise of power both within the science discourse community and in the wider societal, political and economic context. Once again, this has implications for my consideration of the ideological assumptions of the genres in my study.

2.3.3.1 How the term 'ideology' has been used

The term ideology has been used with a wide range of meaning, sometimes with neutral, but usually with negative connotations. In sociology it is used neutrally to mean systems of meaning or belief (Thompson 1990:5) or a body of ideas characteristic of a particular social group (Eagleton 1991:1). This neutral definition is not concerned with reality or unreality. By contrast, most negative definitions are preoccupied with the question of truth/falsity. Ideology is seen as illusion, distortion and mystification, and functions to establish and maintain power (Eagleton 1991:5). Thompson (1990:56), for example, defines ideology as "the ways that meaning serves to establish and sustain relations of domination".

I agree with Eagleton (1991) in finding both neutral and negative meanings of the term ideology useful. Within scientific discourse it is easy to think of ideology in terms of values and beliefs. For example, as I suggested above, objectivity is a central value of the scientific community. To gain the authority of a fact, a proposition must be accepted as objective by the scientific community. Within the scientific community the role of scientific discourse in relations of domination is probably limited to gate-keeping functions associated with access to funding and decisions concerning publication of research articles (and thus whether the knowledge claim of the article becomes accepted as fact). In the wider context of society, as Lemke (1990:129) points out, science plays an even greater role in relations of domination. A current South African example is the debate about the causal relationship between HIV and AIDS between President Thabo Mbeki (who denies a causal link) and AIDS activists, supported by the media, (who insist that HIV does cause AIDS). As Lemke (1990:129) suggests in his discussion of the power of the "mystique" of science, to bolster their claims, both sides invoke the authority of scientific experts (the so-called "AIDS dissident" scientists on the one hand and the Medical Research Council on the other). The authority of science is used by both sides in the exercise of power: the President justifies policy and government expenditure by reference to scientific authority and the highly vocal criticism of his policies by AIDS activists and media is viewed as threatening to the authority of the government. For example one AIDS clinic that supplied anti-retroviral drugs (in conflict with government policy) was forced to close because it was "trying to bring down the government".

Although both the neutral definition of ideology as 'values' and the negative definition of ideology as concerned with relations of domination are useful, I find a variation on the negative definition by Gee (1990) even more valuable in my analysis of scientific discourse. Gee (1990:104) views ideology as "any theory one holds (overtly or tacitly) about the distribution of 'goods' in society", the 'goods' being status and solidarity. I find this definition useful because, as Myers (1989) shows, writers of research articles are at pains to show deference to and solidarity with the research community. By offering the 'goods' of deference towards and solidarity with the research community, writers increase their own chances of achieving the 'goods' of status as represented by acceptance of their knowledge claims by the scientific community, subsequent citation of their publications, funding of research and an increased gate-keeping role: the ability to decide on the factual status of other knowledge claims.

Althusser (quoted in Eagleton 1991:19) suggests an affective rather than reasoned/ /cognitive theory of ideology. In this affective theory, ideology expresses the speaker's attitude to the world, "coded into a discourse that looks like it is describing the way things are" (Eagleton 1991:19). As feminism has made clear, power relations pervade family relationships at a personal level, where inequalities have been naturalised to the extent that they seem to be natural, merely the way things are. Power relations in science discourse are not on this personal level, but in a similar way they intimately pervade the language of science at the level of the lexicogrammar, and for example impersonal, passivised language is apparently, normal, inevitable, "the way things are"

In summary, I find three meanings of the term 'ideology' useful. Its meaning as 'beliefs or values characteristic of a social group' is useful in discussing the culture and Discourse of science. Secondly, a negative meaning of the term as sustaining relations of domination is useful in a consideration of the ways that the authority and "mystique" of science are used by powerful individuals and institutions to justify policy decisions. Finally, Gee's (1990) view of ideology as concerned with theories about the distribution of the 'goods' of status and solidarity is useful in an analysis of science genres, where the exercise of power is more subtle than is implied in a definition concerned with maintenance of domination of one group by another. I draw on these three senses of the term repeatedly throughout the thesis, in particular in sections 4.1.6, 4.2.6, 4.3.6, 4.4.6, 4.5.6 and 4.6.6.

2.3.3.2 Power, ideology and discourse

In this section I consider how ideology, as the means through which consensual power is exercised, is sited in discourse, as well as the notion that ideology in discourse is not only involved in reflecting reality, but also in creating it. This is important for my purposes because discourse is the main way that people are exposed to ideology, in scientific discourse no less than in, for example, political speeches. Control of discourse and its conventions is one way that institutions and the state maintain power (Fairclough 1989:37). Fairclough (1989:33) distinguishes between coercive power (e.g. the power of the state maintained by police, army etc) and consensual power (e.g. that power maintained through discourse in education, law, the media etc). Eagleton (1991) points out that ideology in discourse does not merely reflect reality, but is constitutive of it. Examples are the ideologies of 'the American Dream' or in South Africa, 'the Rainbow Nation'. By conceptualising South Africans in this way, Nelson Mandela and Desmond Tutu made it more likely that South Africans would see themselves as harmoniously diverse but unified.

In discussing how institutions maintain power through discourse, Fairclough (1989:39) points out that people occupy social roles within institutions (e.g. teachers and pupils in a school). From a negative perspective, these social roles constrain what people can or cannot do or say and the discourse types they can and cannot use For example a teacher and pupil who engaged in triadic dialogue (question response evaluation (Lemke 1990)), would be unremarkable, while a teacher who imported the discourse of the courtroom, or news sportscast into the classroom would require explanation. On the positive side, the discourse types available to people are resources they can draw on (Fairclough 1989:39). For example a scientist who wishes to publicise and get recognition for findings can draw on the research article as a resource, and doesn't have to invent a new form.

Eagleton (1991) outlines 6 ways in which ideological strategies, that is ways of ensuring that ideological assumptions take root, are promoted:

- Promoting beliefs and values congenial to the discourse community. (An example is found in chapter 4 in the extent to which all four genres in my study promote the value of objectivity of science).
- Naturalisation. (*Naturalisation* of a genre happens when the discourse type so dominates an institution that other genres are suppressed and the dominant discourse no longer seems to be just one way among many of seeing/expressing things but rather the natural and only legitimate way. Naturalisation is illustrated in Bazerman's (1988) account of the history of the development of the research article. He shows that the demonstration of continuity with previous research findings found in the introduction, the explicit recount of research method found in the method section etc. has become not just one way of presenting research findings to the scientific community, but the dominant way).
- Universalisation. (Latour and Woolgar (1979) show how propositions become universalised through the omission of human agency, eventually gaining factual status).
- Denigrating rivals. (An example is the labelling of "AIDS dissidents" in the example discussed above).
- Excluding rivals. (An example is failing to cite opposing viewpoints in a research article).
- Mystification. (An example is that although very few South Africans have any understanding of viral transmission, many are convinced by the authority of science alone to take one side or other in the AIDS debate).

Fairclough (1989:92) warns that the explanations people give for their own discourse practices should be viewed as rationalisations that serve to legitimise apparently common sense practices. An example of this relevant to my thesis is citing of references in research articles, which is often explained as allowing readers to read the cited work themselves. However, another reason is crediting other researchers and thus paying proper respect to the discourse community. This indicates that the common-sense reason for citing references may be masking an ideological reason for doing so. Also, work that shows continuity with already accepted findings is more easily accepted by the discourse community than work that makes a break with tradition.

Fairclough (1989:43) distinguishes between power in discourse (i.e. discourse as a place where power relations are exercised) and power behind discourse (i.e. how conventions associated with social institutions are shaped by power relations in social institutions and society as a whole). In discussing power in discourse, Fairclough (1989:46) indicates that the more powerful participants in any interaction control and constrain the contributions of less powerful participants in three ways. These are the *contents* of what is said, the *social relations* people enter into in the discourse (whether they are known to each other and how equal they are), and the *subject positions* (roles) they occupy. If there are systematic constraints on the contents of the discourse (i.e. on what is considered important enough to include) this will have long-term effects on the knowledge and beliefs of the institution or society (Fairclough 1989:74). An example pertinent to my own study is the way that science research articles regard only sources published in research journals as legitimate, while popular articles regard as legitimate information from research articles, interviews and conference presentations. Similarly, if there are systematic constraints on the social relations enacted in a discourse or the social identities enacting the discourse, this will have effects on the social relationships and social identities of an institution or society (Fairclough 1989:74).

In summary, ideology, which is sited in discourse, can take a number of forms including promoting beliefs congenial to the discourse community, naturalising or universalising a particular behaviour or way of doing something so that it becomes the only reasonable or legitimate way, denigrating or excluding rivals, and mystifying knowledge.

2.3.3.3 Varying access to resources

In my discussion of the meaning of the terms 'ideology', I have suggested that Gee's variation on the negative definition of ideology, theories about the distribution of the 'goods' of status and solidarity in society, is useful in the analysis of the function of ideology in scientific texts such as research articles. I will consider Myers' (1989) analysis (on which I build in my thesis) of the tacit understanding by writers of status and solidarity in research articles in the next section. I have also suggested that a negative definition of ideology as involved in sustaining relations of domination is useful in examining the role of science in society as a whole. In this section I examine how science and ideologies about science function in relations of domination by those with political and economic power, and look at scientific resources to which different groups in society have differing access.

This is of particular relevance to my third research question, concerning the pedagogical applications of my analysis of the texts in my study, which I discuss in chapter 5.

For Thompson (1990:58), symbolic forms (such as utterances, images and texts) are not just representations of underlying social relations but are rather involved in creating and sustaining social relations. According to Thompson (1990:59) these relations of domination are achieved in the following way:

> There are systematic differentials in terms of the distribution of, and access to, resources. Individuals have, by virtue of their (social) location, different quantities of, and different degrees of access to, available resources. The social location of individuals, and the entitlements associated with their positions in a social field or institution, endow them with varying degrees of 'power', understood as a socially or institutionally endowed capacity which enables some individuals to make decisions, pursue ends or realise interests.

Domination results when established relations of power are systematically asymmetrical i.e. when some groups have power that excludes and to some degree is inaccessible to other groups.

The science resources to which people can have varying access include the literacies required to study science, education and information, and decision and policy-making. I will discuss each of these in turn. In terms of the literacies required to study science, the work of Heath (1986) indicates that access to school-based literacies depends on the literacies previously acquired by a child. Home-based literacy practices of different groups (Heath studied two working class groups and a middle class group) mesh with school-based literacies to varying degrees. Schools take more account of the prior learning experiences of middle class children, and regard these as the norm, making it easier for middle class children to acquire school-based literacies including scientific literacies. If South Africa wants to increase the number of school children doing maths and science at high school level, it is important for schools and for the curriculum to take account of the prior learning experiences of their pupils and of community values and beliefs. Science must be presented as consistent with rather than in opposition to community values. (A South African example is explaining the biochemical processes (such as enzyme action and fermentation) associated with a culturally valued activity such as beer-brewing without denigrating or ignoring its cultural and religious significance (communication with ancestors).)

Fairclough claims (1989:64), that less powerful people are actively excluded from particular types of discourse. A blatant example is provision of unequal education under apartheid, and deliberate limitation of access to subjects such as Maths and Science. This exclusion and limitation continues for economic and logistical reasons (such as historical limitations of the responsible bureaucracy and the time it takes to properly equip a school), which thus need consideration as well as ideology. However Fairclough (1989:65) points out that in societies that are more egalitarian than apartheid South Africa and where financial constraints are less pressing than in present-day South Africa, inequalities continue to be reproduced: in general children come to occupy the class positions of their parents. The role in this process of societal beliefs (such as science as too difficult for most people) is apparent in Lemke's (1990) study of classroom interaction in U.S. secondary schools.

Lemke (1990) provides evidence of pervasive classroom and societal belief that science is difficult and only accessible to the intelligent few. Lemke (1990:138) maintains that scientists are viewed as experts, that science is opposed to rather than continuous with common sense, and that most people are not able to understand it. Further, Lemke (1990:140) shows that science is presented as authoritative. He provides evidence from classroom interaction that pupils are told there are laws in science and encouraged to believe in them even if the explanation is not provided at present. Fact is presented as objective and as in opposition to theory (rather than being, in Lemke's terms, a theory not currently under question). These two wide-spread ideologies (in the neutral meaning of 'beliefs' as well as the negative meaning concerning sustaining relations of domination) – that science is difficult and that science is authoritative - make it more difficult for students to learn science. They make it more likely for students not to try to understand science (because it's too difficult), or to feel pressure to believe ideas they don't understand because they have the stamp of science on them. Thus Lemke (1990) implies that one resource to which people have varying access is knowledge.

In addition Lemke (1990) maintains that the really important resource to which people have varying access in science is decision and policy making and that 'technocrats' (policy-makers in government and industry) control this resource. These technocrats use science to justify their decisions and limit understanding of science to prevent challenges to the basis for the decisions they make. A recent local example was the proposed mining of the St Lucia dunes (in Kwa-Zulu Natal, South Africa). In this case the ecologists working for the mining company suggested no long term damage from the mining (Goedhals 1990), while the more independent environmental impact assessment (Kruger, van Wilgen, Weaver and Greyling 1997) disagreed. Here both those in favour of the mining and those against it used the authority of science in an attempt to influence the decision. Similarly, in the above-mentioned controversy concerning the cause of AIDS, President Thabo Mbeki – who plays a major decision-making role in South Africa about the appropriate response in South Africa to AIDS - gives his own belief (that HIV does not cause AIDS) credibility by quoting various scientists and scientific studies that support his belief. Both these examples illustrate Lemke's (1990) contention that there is domination of one group (ordinary people) by another group (the technocrats -- in the St Lucia case the mining company, and in the HIV-AIDS case the SA government) by their manipulation of a third group (scientists) and the knowledge they produce. Lemke (1990:129ff) notes that it benefits technocrats if people don't understand science but believe in its authority because then they are less likely to question decisions. This lack of understanding is evident in the HIV-AIDS example. Very few people have any understanding of transmission of viruses, immunity to pathogens, immune deficiency action of anti-retroviral drugs etc., but, guided by the media, most middle-class South Africans accept the mainstream medical solution to the problem and roundly condemn Thabo Mbeki's policy. The role of the scientific community as the authoritative experts on which writers of popular scientific articles draw is discussed in chapter 4. This is valuable in my consideration of my second research question (cf. 1.2), which concerns the ideological assumptions of texts in my study.

2.3.3.4 Power relations in science research articles and other science genres

As discussed above, Gee (1990) defines ideology as theories about the distribution of the 'goods' of status and solidarity in society. In this section I consider Myers' (1989) analysis of a tacit understanding by writers of research articles of the distribution of status and solidarity in research science. This account is central to my analysis of ideological assumptions in the texts I analyse in chapter 4.

In his discussion of power relations in science research articles, Myers (1989) uses Brown and Levinson's (1987:58) analysis of politeness in discourse in which a 'model person' has negative face (the want to be unimpeded) and positive face (the want to be approved of). To maximise benefits to him/herself and minimise any loss of face, the model person evaluates the variables of social distance between speaker and hearer, differences in power between speaker and hearer, and the relative size of the intended imposition on the face of their hearer. He notes the assumption in science that the research community is very much more powerful than the individual. Although the assumption is that individual researchers are equal in power, all individual researchers must show deference to the research community as a whole. Readers of research articles represent this powerful community, and writers are therefore writing for an audience more powerful than they are. Myers (1989) suggests that writers have to take account of, and show deference to two audiences: other researchers in the field (what Myers refers to as the 'esoteric audience') and other scientists outside the field who may show an interest in the work (the 'exoteric audience'). Writers of research articles must show politeness to this second audience by providing enough background information for them to understand the article and thus feel included in the research. Secondly and very importantly, writers must persuade other researchers in the field that the research was performed accurately and repeatably etc., and that the conclusions reached are informed by objective observation, rather than the writer's own wishes or preferences.

According to Myers (1989), by putting forward new knowledge claims which supersede prior ones, writers of research articles threaten the face of other researchers who will have to change their practices/ideas. Other face threatening acts in research articles are naming, speculating, and asserting priority. Writers of scientific research articles mitigate the threat to the face of other researchers in a number of ways. For example, a writer who criticises the work of another researcher, may include him/herself in the criticism. Writers often identify common goals, or assume the readers share their goals. An example in my data is found in my extract from a research article, where the authors include the reader ('we') in the implications section of their article (see section 4.1):

> *A first question is whether we are seeing the effects of a purely biological phenomenon or whether periodic extinction results from recurrent events or cycles in the physical environment.*

To avoid threats to the face of readers, writers of research articles also hedge claims, use impersonal constructions or limit claims to themselves. An example from my data is the following extract from a research article in which the authors limit their claim to themselves: '*we favour extraterrestrial causes*' (see section 4.1.1.1). In Myers' analysis this weakens what they say, as they are admitting that the opinion is limited to themselves.

Halliday (1993:68) regards the grammatical features of scientific English – nominalisation, clauses embedded in the nominal group, relational processes, simple clause structure - as "functional in the effective construction of reality", viewing nominalisation as "an essential resource for constructing scientific discourse" (1993:61). For example he shows (1993:58) how, for example, in describing an experiment, the writer wishes to foreground (by making thematic) the goal of the process rather than him/herself. For this purpose use of the passive and removal of the writer from the writing may function in achieving "the balance of information the writer intends" (Halliday 1993:58) rather than merely in making what is said impersonal. By contrast, as indicated above, Myers (1989) views some discourse features of science as functioning ideologically. In his analysis, these features of scientific discourse are a consequence of politeness that must be displayed by individual members of the community to the powerful discourse community as a whole. In this view these features reflect a set of ideological assumptions about social identities, relationships and power that members of the scientific community accept, and which have become conventionalised. My analysis in chapter 4 uses both perspectives. It considers how the discourse features of science function in constructing meaning, and also considers how they function in constructing and maintaining power relationships through deference shown by individuals to the powerful discourse community.

2.3.3.5 How propositions become fact in science

So far in my discussion of ideology I have considered the usefulness of a range of meanings for the term to my analysis of scientific discourse: ideology as beliefs/values, ideology as meaning that sustains relations of domination, and ideology as theories one holds about the distribution of 'goods' such as status and solidarity. I have discussed how ideology in discourse is the vehicle for maintenance of consensual power, and how ideology in discourse does not merely reflect reality but is partly responsible for creating it. I have considered the power relations between participants (reader, writer and scientific community) in various genres of scientific discourse. I have given attention also to the resources to which powerful members of the scientific community have relatively greater access and considered how in the wider society the power to make decisions is bolstered by powerful individuals and institutions by reference to the authority of science. In this section I turn my attention to how a proposition acquires factual status within the scientific community. This is an important aspect of my comparison between genres in chapter 4, and is central to my second research question concerning the ideological assumptions of the genres in my study.

Science tries to describe and explain Nature, to suggest laws that will predict how things will behave not only here and now, but universally. For example Newton's universal laws of gravitation predict how two bodies will behave not only on earth, but anywhere in the universe. So science seeks to establish knowledge that holds universally true, independent of time and place, and independent of who is observing or measuring what is taking place. Some research has been done by sociologists of science into how any scientific proposition comes to be regarded as fact.

Latour and Woolgar (1979:174) note that by 'fact' we usually mean "some objectively independent entity" In general we view facts as pre-existing, and their existence as requiring revelation. Latour and Woolgar (1979:178) quote the following extract which indicates the belief on the part of the writer that facts are somehow "out there" and the role of the scientists is just to reveal them:

> "We can easily imagine a world similar to ours, containing the same intransitive objects of scientific knowledge, but without any science to produce knowledge of them... In such a world, which has occurred and may come again, reality would be unspoken for and yet things would not cease to act and interact in all kinds of ways." (quoted in Latour and Woolgar 1979:178).

For this author, facts are "intransitive *objects* of scientific knowledge," which exist even if there is no science or scientists. This idea of facts as existing and waiting to be discovered by scientists is very widespread. I recently found the following statement in some lecture notes for teachers doing a Bachelor of Education (CASME, 2000):

> "Ideas which just seem interesting in themselves, but don't have any importance for funders, won't be investigated – and so a lot of interesting facts may remain *undiscovered*" (my italics)

Unsurprisingly, research into the beliefs about science of school children indicate similarly that most children view science as a series of discoveries of pre-existing facts (Duveen, Scott and Solomon 1993, Ryan and Aikenhead 1992). There is little understanding amongst school children of the socially negotiated aspects of science (Driver, Leach, Scott and Millar 1994). The assumption in schools according to Selley (1989) is that there is 'a simple logical path from evidence to theory'.

Sociologists of science have disputed this view of facts as pre-existing entities awaiting discovery by scientists. Latour and Woolgar (1979:174) for example suggest that facts are socially constructed (through intuition, interpretation of data, suggestions, discussion between colleagues, reading other sources, publication, and acceptance by other scientists). Pinch (1985) provides evidence for the reliance of facts on human judgement and interpretation of data, and thus for the socially constructed nature of scientific fact. In the physics research articles he studied, he (1985:6) found a chain of evidence, where measurement of substance/phenomenon A was used as evidence for substance/ phenomenon B, which in turn was evidence of substance/phenomenon C. He describes how "splodges" on a graph were taken as evidence of Ar^{37}, which in turn was taken as evidence of solar neutrinos. In science, proof can usually only be provided indirectly at several removes from what is being measured. At each step the final results (in this case measurement of solar neutrinos) can be challenged by other researchers if they can challenge the assumptions and observations involved in the intermediate steps (in this case the interval on the graph where the "splodges" can be regarded as significant or whether the Ar^{37} was caused by solar neutrinos or something else altogether.)

In chapter 4 I describe a similar situation in my exemplary research article by Raup and Sepkoski (see appendix page 3). It is of course impossible to measure directly how quickly mass extinctions that happened millions of years ago occurred. Raup and Sepkoski's measure of the timeframe of mass extinction is through statistical manipulation of counts of fossils. The subject of one of the popular articles in my study (from Scientific American, see appendix page 23) is the evidential challenge by another researcher (Hoffman) to Raup and Sepkoski's findings. Hoffman, (as Pinch (1985) found in his study of the solar neutrinos), challenges the intermediate steps, and suggests that there are uncertainties in Raup and Sepkoski's fossil dating. Hoffman also challenges Raup and Sepkoski's manipulation of their statistics (see section 4.2).

Latour and Woolgar (1979) provide a third example that demonstrates the inevitable role of human judgement in the construction of scientific facts. They investigated a biochemical laboratory that was trying to work out the molecular structure of a substance present in the brain called TRF. To do this they synthesised a number of possible molecules and compared them to the TRF that they had extracted from rats' brains. This comparison used machines that provide graphical evidence of measurements. (They call these machines "inscription devices"). The graphical evidence produced by these machines was then subject to the judgement of scientists, who had to decide whether the graphical tracing made for any of the synthetic molecules was identical with the graphical tracing for the extracted molecule or not. Thus the 'fact' that one of the synthesised molecules is identical with the extracted molecule is the result of human judgement. As Latour and Woolgar (1979:145) note:

> "Difference and identity do not exist per se; rather they depend on the context in which they are used and on negotiations between investigators. It was thus possible to dismiss a difference as minor noise or to deem it a major discrepancy."

During the 7 years in which the biochemical laboratory was researching the molecule TRF, their published papers were couched in terms of modality indicating that the laboratory chose to look on these differences (between the synthetic and extracted molecules) as discrepancies rather than as minor noise. The research group eventually developed a new technique whose results, showing that the synthetic and natural molecules were identical, were accepted by everyone in the field. After that the existence and structure of the molecule became established as fact and references to this were no longer modalised (Latour and Woolgar 1979:147). It is acceptance by the scientific community that turns a knowledge claim into a fact.

However, even after acceptance of a statement as fact by the scientific community, it can still turn out to be artefact (Latour and Woolgar 1979:176). So, for example, before Galileo and Kepler and others proved mathematically that the earth and other planets move around the sun, it was well accepted as a fact by the scientific establishment that the other planets and the sun move around the earth. This fact was supported by careful observations and mathematical calculations, and also had predictive value and was used for navigation. This was a fact that was subsequently found to be an artefact.

Latour and Woolgar (1979:176) note that within discourse a statement stabilises as a fact when it rids itself of place, time, and reference to its producers and the production process and becomes incorporated into a large body of knowledge drawn upon by the discourse community (Latour and Woolgar 1979:106). Independence of time and place indicate that the fact is universally true, while independence of human agency indicates objectivity in science. It is because facts are regarded as pre-existing, independent of people, and just waiting to be revealed, that objectivity implies removal of human agency, and independence of time and place. However, this must be seen in the context of the broader western cultural value in which emotion is seen as the polar opposite of reason. We prove that something is true, valid, credible and thus a fact, partly by representing it as based on reason, not on emotion. Associated with this is the removal of people from our account.

The following quotation is from an interview with an eminent South African physicist, speaking about the purpose of student laboratory work (Parkinson 1995:88):

> "We're trying to get them to learn to do the thing in a dispassionate way; in other words not having a vested interest in the results. Of course everybody's got a vested interest in the result - but learning how to remove one's personal feelings, the feeling that there's a right answer from it. That's a very hard thing to do."

This goal of experimental objectivity is, this informant tells us, an ideal rather than a possibility. The attempt at objectivity must also be reflected in the way we write about our experimental work. So even when we report on research that we personally have done, human agency is removed. It doesn't matter who did it, what matters is that we inform the reader what was done so that they can, if they wish, reproduce the research.

Campbell (1975) suggests that impersonality in science is a convention to persuade readers of the writer's objectivity and lack of personal involvement and emotion. This is not to say that objectivity in science is a fiction. Researchers in any field strive for their research to reflect reality rather than what they would like. This accounts for the careful accuracy of measurement in science. However Campbell (1975) argues that complete objectivity is never achievable because this would imply lack of any person behind the writing, lack of point of view, judgements and selection necessary for the research to be done. For Campbell (1975:397) the positive ideal of the impersonal scientist questing after objective truth as well as the negative ideal of the cold unfeeling mechanistic scientist are personae of scientific discourse. That is they are not the "real scientist" who is writing but rather the "created personality put forth in the act of communicating". So in scientific writing the writer must assume the persona of the objective rational scientist. It is the personae of scientific discourse that claim the achievement of objectivity in the research described (Campbell 1975:399).

Impersonality removes human agency from the account, making it, Lemke (1990) claims, more difficult for those not familiar with the discourse (such as school children) to understand, thus limiting access to the discourse of science. When writers of science research articles use personal language, they are signalling weakness in their argument (Myers 1989) They are indicating that this opinion is limited to themselves, and that they are unable to make the claim that this is an accepted fact. Scientific discourse removes human agency because in the western cultural tradition a personal account is less objective and less credible than an impersonal one. In the discourse of science, because it is centrally concerned with the establishment of the fact, this value of objectivity and thus of impersonality becomes very important. How texts achieve an impression of objectivity is an important point of distinction between genres in my study. As the reader will see later in the thesis, impersonality is not a universal way of achieving objectivity in writing about science. My report on popular science discourse in sections 4.3 and 4.4 shows that popular science does not remove people from the account, and achieves the impression of objectivity differently from research science.

In this review of the literature concerned with ideology, I have argued that the authors of scientific genres such as research articles and textbooks are successful at communicating what they do for the very reason that they do participate in the ideological value of objectivity and its cultural realisation in removal of emotion and the personal. Thus grammatical features are not <u>either</u> ideological <u>or</u> functional. Instead some grammatical features are functional <u>because</u> they allow a text to reflect the ideology of the discourse. In this case an ideological value of western culture, in which personal feelings are regarded as indicating subjectivity, finds even greater importance in the discourse of science because facts and the establishment of facts is so important in science. Within the scientific discourse community, impersonality implies objectivity, which in turn makes it more likely that claims will be accepted by the scientific community and achieve the status of fact. In the wider societal context, propositions accepted as fact by the scientific community have authority, and powerful individuals and institutions employ the authority of science to justify policies and decisions. Lemke (1990) argues that it is to the benefit of such policy makers that most people do not have an extensive understanding of science, so that the basis for governmental or industrial decisions cannot be questioned.

2.4 Scientific genres

This study, as I first indicated in the opening chapter, examines a number of science genres: research articles, university textbooks, popular science texts, and science books for children. Most previous work on science genres has been on research articles (e.g. Bazerman 1988, Myers 1989, Butler 1990, Hunston 1994) and textbooks (Myers 1992b, Love 1991, 1993, Tadros 1989, Wignell, Martin and Eggins 1993, Martin 1993, Veel 1997) with some interest having been shown in popularisations (Myers 1989, Fahnestock 1986, Garcés-Conejos and Sánchez-Macarro, 1988). In what follows I review the literature associated with research articles and textbooks, and in the next section (2.5), I review the literature associated with popular science articles. Because the work on research articles is particularly rich, I look briefly, first at an important study that examines rhetorical aspects of the research article, before reviewing studies that shed light on the linguistic features of the genre. I draw extensively on insights from these studies in the analysis I provide of my own data in chapter 4.

2.4.1 Rhetorical aspects of research articles

The research article is an important genre for my study, because it is the genre against which I measure the other genres in the study, in particular, textbooks and popular science articles. An historical perspective, indicating the common origin of research articles and popular articles, is therefore useful. In his overview of the development of the research article, Bazerman (1988) stresses the fluid and dynamic nature of the research article (and indeed any genre). He indicates (1988:80) how the genre has developed in response to the need to convince readers who had not been present to observe the experiments reported on for themselves. Bazerman (1988:77) points out that in the early days of research articles (i.e. before 1800) experiments were demonstrated to the Royal Society before an audience. Research articles were therefore closer to news, merely reporting that the experiment had been demonstrated, and not really needing to persuade the reader – because witnesses had seen it. Nature was portrayed as speaking for itself. Later Nature began to be viewed as more opaque, more an issue of contention. Experiments then were reported in more meticulous detail, and the authors, knowing that their writing could be challenged, were careful to persuade the reader with reasoned argument. To do this, the writer had to establish that he, the only witness of the experiment, was a credible witness who had followed proper procedures (Bazerman 1988:140). The method had to be provided in enough detail to convince readers and allow replication.

Bazerman (1988:92) shows how in the only research article Newton published, to persuade his readers who had not observed his experiments, Newton used the rhetorical device of representing himself as an ideal experimental scientist who isolates phenomena and reasons in a planned and orderly way. Newton's persuasive use of language has been widely influential. Halliday (1993) notes the continuing influence of the grammatical features of Newton's writing. In the next section (2.4.2) I therefore review Halliday's (1993) analysis of how Newton's use of language for reporting of experiment, complex reasoning and persuasion is reflected in the grammatical feature of nominalisation (an important category in my discussion in chapter 4).

Tracing later developments of the research article, Bazerman (1988:257) uses the example of articles in psychology, to show how the structure of research articles changes to reflect the ideology of the discipline. Similarly he shows (1988:278) how the length of the literature survey and the number of references to the literature depends to a large degree on how focused the discipline is and how much consensus there is in the discipline. He found (1988:153) that as a discipline develops it becomes increasingly embedded in theory and knowledge rather than methods or experimental instruments.

Bazerman (1988:27) notes that in research articles the previous literature, audience and author seem to work together towards a common reflection of nature. This is because the research article sorts out the previous literature according to how well it fits the present claims. As a way of establishing solidarity with the readers, the readers are assumed to share the author's view of the literature and the approach to the object of study. The author's presence is minimised in favour of the author's presentation of nature. The claims made by the research article are represented as filling a defined slot. To achieve this the author defines a problem or substance, giving it an existence it may not have had before. For example, as noted above in section 2.3.3, substances and concepts are assumed in research articles to pre-exist their identification and isolation (Bazerman 1988:28). The object of study is taken as a given, and human action is viewed as mere coming to know an existing object.

2.4.2 Grammatical features of research articles

Complementary to Bazerman's tracing of the rhetorical developments of research articles, is Halliday's (1993) analysis of the historical development of certain grammatical features of scientific writing such as nominalisation. Through nominalisation, actions, events and qualities are construed as nouns, and thus represented as objects (Halliday and Martin 1993:52). Halliday (1993:54ff) shows how nominalisation packages previously explained complex argument. It allows the efficient progression of complex argument by allowing previously explained (and thus Given) material to be placed in thematic (and thus unmarked position) in relation to the New material (as unmarked Rheme), which is also the new step in the argument. Another important result of nominalisation explicated by Halliday (1993) is the preponderance in scientific English of relational processes. With actions and events (process) being construed as nouns (things), less meaning is sited in the verb, and verbs in scientific writing are often the relatively empty 'be' or causal verbs. So, commonly, science is expressed as 'x = y' or 'x caused y'.

The research article most commonly follows the Introduction-Methods-Results-Discussion structure as noted by Kourilová (1994), and as prescribed also by the APA Publication Manual (Bazerman 1988). These sections have quite distinct linguistic features. For example Hanania and Akhtar (1985) found that active verbs exceeded passives in all sections except methods. Similarly the present tense exceeds the past in all sections except methods. Modals were highest in Discussion and lowest in Methods. Tarone, Dwyer, Gillette and Icke (1998) found that *we* + active voice marked the authors' own work or own procedural choice, while use of the passive marked the work of others or a standard procedure.

A large body of literature exists on modality in scientific research articles. A number of corpus studies have looked at the frequency of modal verbs in science texts. Butler (1990) looked at the frequency of modals in science research articles and textbooks and Hanania and Akhtar (1985) examined their frequency in Masters theses in science. These studies confirm that different sections of a science research article are likely to have different concentrations of modal verbs. Modality is generally employed by writers to modify or soften what they say, or to introduce a deliberate element of vagueness. Work on hedging is useful for my purposes in this study as it throws light on the writers' opinion of what they are writing about and their relationship with the reader (Lakoff 1972, Myers 1989, Dubois 1987, Salager-Meyer 1998, Channell 1990, Powell 1985, Crompton 1997, 1998) . In Hyland's formulation (1994, 1996a, 1996b, 1997), writers may hedge to indicate the extent to which they feel a proposition corresponds to reality, they may hedge their own responsibility for the proposition itself by attributing it to someone else, or they may hedge out of politeness to the reader. My findings in chapter 4 indicate that the different genres in this study have a preponderance of different sorts of hedge, and this is one of the features that distinguish the genres in my study.

Another perspective on writers' opinion of what they are writing about and their relationship with the reader is found in a further concept which is central to this study: evaluation (Hunston 1993, 1994, Thompson and Yiyun 1991). Evaluation includes those elements of a text that function to express the writer's opinion and reflect the writer's value system, construct and maintain relations between writer and reader, and to organise discourse (Thompson and Hunston 2000:6). In the term 'evaluation' Thompson and Hunston (2000:3) include expressions of opinion about entities (usually referred to as modality) and expressions of opinion about propositions (referred to by other researchers as attitudinal meaning, appraisal, and evaluation). Hunston (2000:176) distinguishes evaluation relating to the content of what is said about the world and evaluation relating to the ongoing interaction between reader and writer. Martin's concept of appraisal (2000a:142) encompasses evaluative lexis that includes expressions of emotion (Affect), moral assessments of behaviour (Judgement) and aesthetic assessments (Appreciation).

In this section (2.4.2) I have reviewed some of the grammatical features of science research articles. Most revealing for my comparison of science writing in four genres (cf. my first research question in 1.2), which I report on in chapter 4, are the features that illuminate interpersonal meaning, namely modality, hedging and evaluation.

2.4.3 Textbooks

Textbooks, central to my study (cf. section 4.2), have been the subject of some study (Myers 1992b, Love 1991, 1993, Tadros 1989) with particular attention being paid to textbooks at school level within the Australian Systemic Functional tradition (Wignell Martin and Eggins 1993, Martin 1993). Swales (1995) characterises textbooks as having a paucity of hedging, a diminution of human agency, use of abstract nominalisation as subjects of processes, a deployment of prevailing metaphors, and the mediation and marketing of difficult material. In his words (1995:4) introductory textbooks are usually "conservative encapsulations of prevailing paradigms. Appearance, arrangement, certitude, and style ... make them examples of 'canonizing discourse'". Myers (1992b:8) suggests that textbook authors arrange currently accepted knowledge into a coherent whole, while by contrast journal article authors try to make the strongest possible claim for which they can get agreement. Readers of articles, according to Myers (1992b:13): sort out new knowledge from old; attribute credit to researchers, assess the certainty of statements; infer cohesive links between knowledge; and trace the relation to other texts. Readers of textbooks on the other hand: arrange facts in order, separate facts from researchers, take most knowledge as accepted, infer knowledge using cohesive links. However Swales (1995) suggests that the readership that writers of textbooks must take into account is more complex than this and that one group of readers that textbook writers address are the academics who evaluate and prescribe the textbooks. Because of the nature of my study, which draws on a limited range of texts, (although these are analysed in the great depth that systemic analysis affords), I found no evidence in my study of any reader beyond students.

Veel (1997:161) discusses the roles that school textbooks (as opposed to lab science) construct for the reader and participants. He notes that school science differs from lab or applied science in the genres it emphasises (considering genre from the perspective of the Australian tradition). In school science explanations and descriptive and taxonomic reports are the most common genres (Veel 1997:167) compared to lab and applied science where exposition and discussion are the most common genres (Veel 1997:168). Veel (1997.168) suggests that this recontextualisation of lab and applied science, to facilitate readers' learning it, makes school science abstract, impersonal and disconnected from the processes leading to its formation. However, as numerous studies make clear (e.g Latour and

Woolgar 1979, Knorr-Cetina 1981), the language of research articles is equally abstract, impersonal and disconnected from the processes leading to its formation.

Veel (1997) maintains that school science texts move through a hierarchy of less privileged genres (such as procedure) to more privileged genres (such as cause and effect explanations). In his terms (Veel 1997:182) a knowledge path is constructed for students from less grammatically complex to more complex scientific language. As they move along this knowledge path students are exposed to language that is increasingly lexically dense, increasingly nominalised, increasingly abstract. There is a move from temporal logical relations (e.g. while, then, after) to consequential logical relations (e.g. so that, if, because), and from external conjunctions (construing the external world) to internal conjunctions (construing the organisation of the text). .

One motivation for my study (cf. my third research question, see section 1.2) is to test the extent to which the non-academic genres (popular science texts and science books for children) are in any way a preparation for the academic genres (specifically, the research article and textbooks). For this reason it is important that I consider here evidence for the extent to which the writing expected of undergraduate science students approximates the writing in textbooks and research articles. Braine (1989) collected 61 assignments in ten science and engineering courses and found that 52 (85%) of the tasks involved a report on a specified participatory experience. Most of these are lab reports, which Braine (1989:9) points out require a mixture of activities such as summary paraphrase, description, comparison and contrast, cause and effect, interpretation and the integration of mathematical and scientific data into a text. In chapter 5 I argue that most of the assignments students are expected to produce (lab reports) are "proto-research articles". These have some of the same functions as research articles: placing the work done in the context of the literature, providing a full enough account of the method used, convincing the reader (lecturer) that the work was carefully and accurately performed, explaining the results with reference to the literature.

As well as having to produce reports on experimental work, the other major literacy event that science students participate in is examinations. In these, other genres are expected of students such as descriptive and explanatory essays, as well as short explanations of phenomena and processes. These, I argue in chapter 5, most closely approximate textbooks. Features that examination answers share with textbooks is that they are summaries of received knowledge, regarded by writer and (ideally) by reader as fact, and unlikely to be hedged to any marked extent. Martin (1993:167) notes that textbooks are the main models of written science for school children.

My outline in this section of studies of the research article indicates that research articles developed both grammatically and rhetorically in response to the need of writers to convince readers of their research claims. Halliday's (1993) analysis of grammatical features of scientific discourse indicates the suitability of features such as nominalisation and thematic development for reasoned argument. Bazerman's (1988) historical survey of rhetorical development of the genre indicates how it developed to convince readers who were not present to observe the research that the writer performed the research in an acceptable way. This section has also considered studies of textbooks indicating features such as intended audience of textbooks, as well as some of the discourse features of textbooks. Veel (1997) suggests that school textbooks become increasingly grammatically complex. This ties in well with and usefully informs my analysis of an extremely grammatically complex textbook extract in section 4.2 (see appendix page 8 for a copy of the textbook extract that I report on in 4.2).

2.5 News genres

Having dealt in the previous section with scientific genres, I turn in this section to the two news genres, the issues report and opinion piece, from which two of my exemplary texts are drawn (see sections 4.3 and 4.4). I review also some of the values of news reporting, before moving on to reviewing studies of the discourse features of popular science articles. This informs the first and second of my research questions regarding what distinguishes the genres in my study from each other, and the ideological assumptions of each genre.

2.5.1 The genres of news reporting

Three popular articles are examined in this study: a text from Scientific American (i.e. written by a journalist for scientists not active in the discipline) and texts from Time and the Mail and Guardian (both written by journalists for non-scientists). Copies of these texts are in the appendix in pages 23, 28 and 35. White (1997) identifies 2 modes within the media: hard news reporting, and commentary or opinion. The two major sub-genres of hard news reporting are the event story and issues report. The first of these is grounded in a material happening, typically some misadventure. The issues report by contrast is grounded in a communicative event and describes the "criticisms, accusations, demands, warnings, discoveries or announcements of some authorised source such as .. a professional expert or scientific researcher" (White 1997:102). Popular science reporting as a result usually falls into the second category – the issues report. The event story reports on a phenomenon, while the issues report concerns a metaphenomenon: a phenomenon commented on by someone else. By contrast with hard news, in commentary or opinion the role of the author is to offer subjective interpretations with explicit value judgements. The Scientific American and Time texts in my study are issues reports, with projected statements of authorised sources. This is distinguished from the Mail and Guardian article in my study, which is an opinion piece with frequent interpersonal value judgements about the competence and motivations of scientists.

2.5.2 The values expressed in news genres

As noted by White (1997:106) and Golding (1997:257) journalistic training manuals stress that news reporting should be factual, neutral, objective and free of bias (e.g. Hutchison 1986:12). To achieve this the news writer allegedly minimises interpersonal meanings, as these foreground the writer's subjective involvement in the text. Such meanings are confined to quoted comments. This does not mean however that interpersonal meanings are eliminated. Instead, according to White (1997:109), they are confined to intensification. This takes the form of lexis (examples from my data are '*seeks*' and '*scrutinise*' instead of 'look for') and comparisons (an example quoted by White is 'the worst losses since 1945'). White (1997:109) notes that because issues reports can rely on the reported words of others to engage the reader emotionally, they do not need to rely as heavily on intensification as do event stories.

In terms of subject matter in news reports, Ungerer (1997:311) found that the following are regarded by journalistic manuals as news values or likely to make something newsworthy: large numbers, proximity, reference to persons, reference to elite people, reference to the negative, predictability/unexpectedness, unambiguity, recency, and continuity of the topic. In my three articles reference to persons was certainly important

(Time and Scientific American) recency is stressed in all three, unexpectedness is stressed in the Mail and Guardian article. Reference to associated institutions and mention of Luiz Alvarez's Nobel prize could be viewed as reference to elite people.

Focusing specifically on science popularisations, Fahnestock (1986:297) maintains that their appeal to readers is either what she calls 'the wonder' (powers and secrets of Nature and breakthroughs of scientists) or 'the application' (further benefits of the powers of Nature of the breakthroughs of scientists). These categories do not fit easily with the highly popular topic in the popular articles in this study (what caused the extinction of the dinosaurs). This topic has greater correspondence to White's (1997:104) identification of 3 categories of subject matter in news reports: aberrant damage, power relations, normative breach. Elements of two of these categories are identifiable in the popular science articles in my study: there is the past aberrant damage that occurred during the impact of a meteorite, as well as the possibility of future aberrant damage should a meteorite ever hit earth again. While the texts in my study do not report on any normative breach, this is a common theme in articles for example on genetically modified food, cloning, pollution, the environment etc. Indirectly, power relations are also reported on in science news to the extent that new findings or hypotheses challenge the existing ones, eliciting responses from those that support the existing hypotheses and theories. The difference of opinion between scientists is part of what is reported on in all three articles in my study to a greater or lesser degree. White's categories therefore have importance for the second of my three research questions, that concerning the ideological assumptions of the genres in my study.

White (1997:125) sees the main purpose of news reports (in their focus on these three categories of aberrant damage, power relations, normative breach) as being the identification of maximal disruption of the status quo. This identification is ideologically informed, in the sense that it relies on assumptions about what parts of the social order are most important and must be monitored for signs of damage, and on assumptions about what forces can potentially damage these important parts of the social order.

2.5.3 Studies of the discourse features of popular science

With respect to popularisations of science, it is interesting to note that in early scientific journals, reports on experimental work accounted for only 5-20% of space in the journal (Bazerman 1988:65). Most of the space in early volumes of the *Philosophic Transactions of the Royal Society* was devoted to material that would today be found only in popular sources: remarkable foetuses, astronomical sightings, and travels to exotic places.

There have been some studies comparing popularisations of science with research articles. Fahnestock (1986), who examined texts from newsmagazines and newspapers, concluded that popularisations hedge knowledge claims much less often than do the research articles from which the information was drawn. Crismore and Farnsworth by contrast (1990:129) found almost as many hedges in popularisations as in research articles. As will be seen in Chapter 4, the popularisations I examine that are aimed at a scientific rather than general audience do not contain fewer hedges than research articles. However my analysis indicates that what is hedged in popularisations is writer responsibility for what is said rather than either expression or the extent to which what is said coincides with reality.

Myers (1991) found that lexical cohesion was more explicitly marked in popularisations than in research articles, and that popularisations vary in their grammatical features, with some popularisations being similar to research articles in some features and others showing greater similarity with fiction. In his study focusing on politeness strategies in research articles, Myers (1989) compares these to popularisations by suggesting that popularisers only have to take account of readers not active in the discipline but who take an interest in the research (what he calls the exoteric community). By comparison, research articles need to take account of this audience as well as researchers in the discipline. However Garcés-Conejos and Sánchez-Macarro (1998) looked at popularisations written by the original researchers (i.e. long articles compared to the short articles by journalists that I analyse) and found that these writers still show deference to the esoteric community (i.e. other researchers in the same field). Garcés-Conejos and Sánchez-Macarro (1998) found that popularisations of science written by the researchers themselves take account of the exoteric audience in a number of ways. These include involving the reader by providing background information (a feature of both the Time and Scientific American articles in my study); making explicit reference to moral issues;

making reference to the human side of readers; creating rapport with the readers by asking rhetorical questions, using colloquial expressions (very marked in my extract for the Mail and Guardian) and addressing the reader directly (see the Mail and Guardian article). In other words, this research has been helpful to me in that it suggests a number of features that illuminate ideological assumptions in popular science and that distinguish popular science from other genres (cf. my first and second research questions, section 1.2).

With respect to the final of the four genres analysed in this study, science books for children, I found no reference to this genre in my search of the literature. It is possible therefore that this is a neglected genre.

2.6 Summary

In summary, this chapter outlines literature that has most influenced my conceptualisation of and analysis that I report on in chapter 4 in this study. As explained earlier, my analysis in chapter 4 involves a Systemic Functional analysis at the levels of register, genre and ideology of texts drawn from four genres of science writing: research article, textbook, popular science and science books for children. Accordingly, I have given attention to the concepts of register (in 2.3.2), genre (in 2.3.1) and ideology (in 2.3.3). To reiterate, a functional approach tries to explain how language is used, and focuses on meaning. Within this approach, register represents the 'context of situation', and is analysed in terms of the three metafunctions of field (ideational or content meaning), tenor (interpersonal meaning) and mode (textual meaning, concerned with how the message is organised). Genre, or Context of Culture, the second level of meaning that I consider, has been variously and usefully viewed in terms of the staged nature of genres, and from a rhetorical perspective in terms of how the writer achieves his/her purpose. Ideology, the third of the levels of meaning within the functional approach that I consider, relies, in my analysis in chapter 4, on analysis of register. My discussion in section 2.3.3 of this chapter indicates the usefulness of three variations of meaning of the term in the literature. These are a neutral meaning (values), a negative meaning related to maintenance of relations of domination and a meaning related to the 'goods' of status and solidarity which allows analysis of power relations in texts such as research articles where there is no apparent domination of one group by another.

Register, genre and ideology in texts in four science genres (research article, textbook, popular science, and science for children) are the focus of my analysis in chapter 4. Section 2.4 therefore is concerned with my reading on two of the genres in my study (research article and textbook), while section 2.5 reviews studies that have influenced my analysis of popular articles. Section 2.4 indicates that both the rhetorical and grammatical features of research articles contribute to their ability to convince the reader of knowledge claims by logical argument and by persuading the reader of the writer's objectivity and reliable performance of the research. Textbooks, characterised by Swales (1995:4) as 'canonising discourse', function to summarise currently accepted knowledge. They, I indicate, construct a knowledge path for students of increasingly lexically dense language and increasingly valued genres. My extracts from university textbooks represent the culmination of this path in lexically dense information report and discussion genres. Hence such information forms a very useful background to my own analysis (reported on in chapter 4). Section 2.5 considers some of the news values that cause a particular area in science to be the subject of popular articles: White's (1997) categories of aberrant damage and power relations and Ungerer's (1997) categories of unexpectedness and reference to people, particularly elite people, are useful to my study.

In the next chapter, I turn my attention to a consideration of Systemic Functional Grammar as a tool for the in-depth and systematic analysis of the discourse features of texts, and explain how text is analysed using this grammar.

CHAPTER 3 DATA COLLECTION AND ANALYSIS

3.0 Introduction and overview of the chapter

This investigation of the differences between popular and academic science could have taken a number of routes. It could for example have involved a broad survey of the subjects that are selected by popular journals and newspapers as worthy of being popularised, compared to other scientific topics that are seldom brought to public notice. Or it could have involved comparison over a large body of texts of a particular feature, such as inclusion of human participants, or use of modality in popular and academic science writing. In this thesis, though, rather than undertake a broad survey of this sort, I have chosen to make a close and detailed study of a very limited number of texts, focussing on one or two texts drawn from each of the four genres in the study. I have chosen to consider what light the grammar of a limited range of texts can shed on the ideological assumptions of the genre from which the texts are drawn. Such an approach enables one access to features not obvious from a surface inspection of the text, and allows one to gain statistical information concerning the discourse features of short typical pieces of text.

In what follows I outline the subject of the texts in the study, and describe the extracts selected, indicating the relationship between each extract and the full text from which it was extracted (in section 3.1). I then go on, in section 3.2, to provide a brief description of the analytical tool that I use in my analysis of the texts in the study: Systemic Functional Grammar. In this account I include not only the grammar of texts (cf. sections 3.2.3 – 3.2.5), but also a consideration of the 'grammar' of images (in section 3.2.6). Copies of the texts in the study, together with all illustrations, are included as foldout pages in the appendix (pages 3, 5, 7, 9, 10, 11, 13, 15, 17, 19, 21, 23, 25, 28, 30, 32, 35, 37, 40, 46, 49, and 51 of the appendix), as are copies of each text divided into numbered clauses (pages 2, 8, 12, 18, 22, 27, 34, 36, 39, 45 and 48 of the appendix).

3.1 Data Collection

This thesis aims to compare popular genres of science with academic genres. The sources of popular science writing included in the thesis are popular science journals, newsmagazines and newspapers, and books for children. The academic sources included are science research articles and textbooks. To keep the ideational meaning of texts constant, I chose a topic that has been popular for the last 20 years both in science books for children and in popular science journals. This is the question of what caused the extinction of the dinosaurs at the end of the Cretaceous period 64 million years ago. Conventional theories have it that dinosaurs died out as a result of slow environmental changes to which they were unable to adapt. The major theory developed in the last 20 years, however, holds that the Cretaceous-Tertiary extinction was sudden and probably initiated by collision with an extraterrestrial body such as a meteorite. All texts in this study reflect this development. Some of the differences between genres in this study are likely to be the result of the topic (and discipline) chosen. Studies such as that by Bazerman (1988) and work done in Systemic Functional Linguistics (e.g. by Martin 1993) indicate that there are likely to be peculiarities in the discourse features of different disciplines (e.g. geology as opposed to physics). Similarly, it is likely that the choice of one topic over another (e.g. dinosaur extinction as opposed to black holes or a cure for HIV or cancer) will have some influence on the discourse features of the texts.

Because my analysis of texts in chapter 4 is deep rather than wide, it can necessarily be of a limited number of texts only. As I mentioned in chapter 1, I originally collected and analysed at a superficial level a much larger selection of texts from each of the four genres than I eventually analysed. I attempted to select for analysis texts from each genre that seemed to me typical of the genre. Texts chosen for analysis are the following:

- From ten research articles originally collected, an extract from a single research article was analysed. I report on this analysis in section 4.1.
- From four textbooks originally collected, extracts from three textbooks were analysed. I report on one of these analyses (from a first year textbook) in section 4.2 making reference to the other two extracts analysed (extracts from a more advanced textbook and from a textbook for non-science students).
- From about 70 popular journal articles originally collected, extracts from three articles were analysed. I report on two of these analyses in chapter 4. Section 4.3 reports on analysis of an extract from a Popular Science journal, Scientific American, analysed in section 4.3, making reference to an extract from a further popular article from the newsmagazine, Time. Section 4.4 reports on analysis of an extract from a South African newspaper, the Mail and Guardian.
- From ten science books for children originally selected, extracts from four books were analysed. Section 4.5 reports on the analysis of one of these books, *Prehistoric Life*, and I also make reference to the three other books analysed.

I now describe each of the texts analysed. I include in this description the texts on which I provide a full report in chapter 4, as well as those to which I merely cross-refer and make comparison. A copy of the original of each text appears in the appendix.

3.1.1 Research articles

As I mention in chapter 1, I originally considered 10 examples of the research article genre. However, as indicated in chapter 2, the research article is the genre that has had the most interest shown in it. As a result I analyse an extract from only one research article in chapter 4. The extract analysed is from the following research article:

- Raup, D.M. and Sepkoski, J. (1984) Periodicity of extinctions in the geologic past *Proceedings of the National Academy of Science 81* pp801-805.

Six paragraphs (916 words) of the article by Raup and Sepkoski (1984) are analysed in section 4.1, out of the total of 35 paragraphs constituting the whole article. On first reading the article I became aware that, as expected, different functions were served by different paragraphs: *Abstract, Introduction/Literature survey, Method, Results,* *Discussion, Implications/ Conclusion*. I chose the six paragraphs, because I wanted to analyse one paragraph of each function. Although the analysis in section 4.1 is not an attempt to compare discourse features in the different subsections/functions, I do comment on differences. The paragraphs chosen are:

- Paragraph 1 (This paragraph is called "Abstract" in the research article, and is analysed as clause complexes 1-5 in section 4.1)
- Paragraph 2 (This paragraph is unlabelled in the research article, but performs the function of *Introduction*. It is analysed as clause complexes 6-12 in section 4.1.)
- Paragraphs 27-29 (These paragraphs are called the "Best-Fit Cycle" in the research article, and constitute the entire *Method, Results* and *Discussion* sections for one of the statistical tests on their data performed by the authors. Sections that perform the function of *Method* are analysed as clause complexes 15-18 in section 4.1, the *Results* are in clause complexes 13-14, and the *Discussion* is in clause complexes 19-25).
- Paragraph 34 (This is found under the heading "Implications" in the article, which attempts to tie the findings of the article (of periodicity in extinction) to the writers' thesis that periodicity has an extraterrestrial cause. Paragraph 34 is analysed as clause complexes 26-36 in section 4.1.)

For reasons of economy, a large continuous section of the research article (paragraphs 3 to 26) is omitted from my analysis. This section is similar to paragraphs 27-29, which *are* included in my analysis, in that in them the authors report on other statistical tests that they performed on their data. I chose the article for analysis since I see it as being representative of discourse in research articles.

3.1.2 Textbooks

Section 4.2 focuses on an extract from a first year geology textbook (which I refer to throughout by its author's surname, Duff). It makes reference to and comparison with analyses (which, however, are not supplied in full) of two other textbooks. The first, referred to once again by its author's surname, McGhee, is aimed at advanced geology students. The second, referred to by its authors' surnames, Trefil and Hazen, is aimed at non-science students. This range of texts was selected to get some idea of variation in tertiary textbooks. I provide information on the relation of the extract to the text as a whole for each of these three textbooks in turn:

- Duff, D. (1998). *Holmes' Principles of Physical Geology*. U.K.: Stanley Thornes Ltd. Page 85.

Duff, (540 words), is an extract from the fourth edition of a first year textbook by Holmes, originally published in 1944. The text analysed is a continuous extract from a chapter on stratigraphy and fossils. It is the only information in this textbook that deals with the topic of the cause of the end-Cretaceous mass extinction. As might be expected from a first year textbook, Duff encompasses a wide range of concepts in geology, taking a shallower look at these concepts by comparison with McGhee.

- McGhee George R (1989) Catastrophes in the history of life. In Allen K.C. and Briggs D.E.G. *Evolution and the Fossil Record*. London: Belhaven Press. 43-47.

The McGhee text (1210 words) is an extract from a textbook aimed at students in years later than first year. The text analysed is a continuous extract from a chapter on mass extinction. It provides a deeper and more detailed examination of the material than does Duff.

- Trefil, J and Hazen RM (1995) *The Sciences: An integrated approach*. N.Y.: John Wiley and Sons Inc. p576.

Trefil and Hazen deal with important ideas in all disciplines in science – not only geology as in Duff and McGhee. The text analysed (560 words) is a continuous extract from a chapter called 'Evolution'. It is thus not the case that the entire chapter deals with geology, and it provides a less detailed and less complex examination of the topic than does Duff.

3.1.3 Popular science articles

Section 4.3 focuses on an analysis of an extract from a Scientific American article. I also make some reference to analysis (not provided in full) of an extract from a Time magazine article. Section 4.4 focuses on an extract from the Mail and Guardian newspaper.

Section 4.3 analyses an extract from the following article from Scientific American:

- (1985) Falling Star? Scientific American 253(3).

The entire text of this article is 13 paragraphs long (1500 words). Again, for reasons of economy, full analysis is provided in section 4.3 of paragraphs 1, 3, 5, 8, 10, and 13 (758 words) only. However a full analysis of all 13 paragraphs is provided for aspects of the analysis in which continuity of the text is important such as theme, conjunction, and evaluation. As expected, the Scientific American article is unlike the research article Raup and Sepkoski in that it does not follow the conventional format of the research article (Introduction, Methods, Results, Discussion Conclusion). Instead the Scientific American article represents one of the sub-genres of news reporting, the issues report (see section 2.5). For convenience I therefore chose the 6 paragraphs indicated above, providing a section of text about as long as the section analysed from Raup and Sepkoski.

As I explained earlier, comparison is made with a 1675-word extract from the following article from Time magazine. This article is also an example of the issues report genre, and thus for reasons of economy, full analysis is not provided of the Time article:

- Angier N. (1985) Did comets kill the dinosaurs? Time May 6 1985

Section 4.4 analyses an extract from an article from the Mail and Guardian:

- Matthews, Robert (1999) Why dinosaurs won't go away Mail and Guardian November 5 to 11 1999 p23.

The extract analysed includes five paragraphs (327 words) from a 27-paragraph article. I chose the five paragraphs because they were the part of the article that dealt with what caused the extinction of the dinosaurs. The rest of the article is a general discussion of the popularity of dinosaurs in the popular imagination, and is not included in the analysis. Thus, unlike most of the other texts in the study, the extinction of the dinosaurs is not the central topic of this article, merely the topic of a small section. Unlike the articles from Scientific American and Time magazine, the Mail and Guardian article is an example of the opinion piece genre, discussed in section 2.5. This difference accounts for the very different interpersonal relations in the Mail and Guardian article compared with the other two popular articles.

3.1.4 Science books for children

Section 4.5 provides an analysis of a single double-page 'chapter' of a book on dinosaurs for children, called *Prehistoric Life*. Four texts were originally analysed:

- Benton, Mike (1990) *All About Dinosaurs* Kingfisher: London. P42-43.

- DK Direct Limited (ed.) (1993) *The Dorling Kindersley Picturepedia: Dinosaurs* Dorling Kindersley: London 46-47
- Johnson, Jinny (1996) *Prehistoric Life* London: Marshall Publishing Ltd. P22-23
- Taylor, David. (1993) *The Prehistoric World of the Dinosaurs: Tyrannosaurus Rex* Boxtree: London pp 26-29

I judged two of these four to be slightly unusual in the following ways. Firstly, *DK Picturepedia* is unusual in that its structure is not linear. Rather the material is structured as blocks of information under different subheadings and associated with different illustrations; the order the reader chooses to read the information in is not important. Secondly, the fourth of the above texts, *Tyrannosaurus Rex*, I judged to be unusual in that the information is first of all rehearsed as a narrative, which in my experience is unusual in a child's science book, before being presented as an information report. The first text above, *All About Dinosaurs*, is very short, and therefore the third of the above texts, *Prehistoric Life*, I selected as exemplary of the genre. I make comparison with the other three texts in section 4.5. As with the other three texts for children, the extract from *Prehistoric Life* forms a double page 'chapter' in the book, distinct from other such 'chapters' on topics such as different major groups of dinosaurs or dinosaur eating habits. In each of the books the topic of how the dinosaurs became extinct forms one such topic.

3.2 Method of analysis

Since I am interested in distinguishing popular from academic genres of science, and also in discovering the ideological assumptions of the different genres I study, I need a comprehensive and systematic means of analysing discourse that enables explanation of the meaning of texts in terms of their grammatical features. Systemic Functional Grammar is a useful tool in such an analysis as its primary focus is on meaning and on the choices writers/speakers make in communicating their message. This focus on meaning is important for my purposes, because it allows analysis not only of grammatical differences, but also of ideological differences. In addition systemic analysis enables a consideration not only of what choices the writer/speaker made, but also of what choices they chose not to make. The choices available to a writer/speaker operate at a range of levels. These include phonology (omitted from this study as all texts are written), register (including what is said, the relationship between the interactants and how the message is organised), and genre (whether the writer chooses some culturally-specific text type as a vehicle for the intended communication). Another essential feature of Systemic Functional Linguistics is its focus on the text rather than the sentence as the basic unit for analysis. This is valuable to me because of my focus on the ideological assumptions of the texts in my study.

In chapter 2 I discussed Systemic Functional Grammar from a theoretical perspective; in sections 3.2.1 – 3.2.6 I provide an overview of Systemic Functional Grammar from a methodological perspective, indicating the major categories I use in my analysis. For reasons of space this overview is necessarily abbreviated and simplified, and gives prominence to features of the grammar that I found to be most useful in distinguishing the genres analysed in chapter 4. The examples used in the overview come, with few exceptions, from my data.

3.2.1 Context of situation and context of culture

As noted in section 2.3, Systemic Functional Grammar situates meaning within the context of culture (genre) and within the context of situation (register). The texts in this study are realised as particular genres. The culture of a particular university department would be associated with a range of genres (such as the common room chat, the seminar presentation of research to colleagues, the lecture etc.), but not with certain other genres (for example poetry, legal genres, or sales pitches would be uncommon). I have examined the notion of genre in section 2.3.1, and the focus of the rest of this chapter will therefore be a description of the grammar at the level of context of situation.

By way of clarification, the context of situation refers to three situational variables (Christie and Unsworth 2000:4): what the topic is (Field), who the interactants are and what their social roles are (Tenor), and how the interactants choose to organise the text (Mode). What is appropriate discourse between lecturer and students, e.g. lecturing, or written knowledge-testing questions set by the lecturer for the students, would not be appropriate between colleagues in the common room. In systemic grammar these situational differences are reflected in three different components of meaning in language, or metafunctions. These are:

- Ideational/Experiential meaning. (This has to do with experience of the physical world/reality. For example, what is a particular lecture about?).

- Interpersonal meaning (This has to do with enacting social reality (Christie and Unsworth 2000:6), with interaction between people, and with attitudes and judgements. For example, who is allowed to speak during the lecture?).
- Textual meaning (This has to do with how a message is organised, and with how the message fits in with other messages in the context in which it is being spoken or written. For example, how does the lecturer signal to listeners where he/she is in the lecture? How does a lecture fit in with previous lectures, with the texts the lecturer has consulted in preparing the lecture, and with less formal consultation between lecturer and student during lab sessions?)

Every clause reflects all three of these structures simultaneously. As the clause is the fundamental analytical unit in Systemic Functional Grammar (SFG), I will start by considering what constitutes a clause, before examining the above three metafunctions in greater depth

3.2.2 The clause as analytical unit in Systemic Functional Grammar

Minimally, a clause has a verbal group, which may be finite (i.e. it shows tense) or non-finite (Thompson 1996:16). Generally clauses also have one or two nominal groups, and they may have prepositional phrases:

1.

Stop writing!
Finite verbal group
process

2a

The impact of the larger comets	spews	enough debris	into the atmosphere
Nominal group	Finite verbal group	Nominal group	Prepositional phrase
Participant	Process	Participant	Circumstance

2b

to block	the sun	for months
Non-finite verbal group	Nominal group	Prepositional phrase
Process	Participant	Circumstance

These prepositional phrases and nominal and verbal groups are at the same *rank* (Thompson 1996:22). This implies that prepositional phrases are at the same level or rank in the grammar as nominal or verbal groups. Both prepositional phrases and nominal groups may be expanded by the inclusion of nominal groups (same rank, enclosed in single square brackets below) or clauses (higher rank, enclosed in double square brackets below):

3 The results [of a test of the extinction record] are illustrated in Fig.4.

Nominal group with embedded nominal group	Verbal group	Prepositional phrase

4 Hoffman's arguments do not rule out the possibility [[that extraterrestrial

Nominal group	Verbal group	Nominal group with embedded clause

4 cont. influences have shaped the history of life]]

Nominal group with embedded clause continued

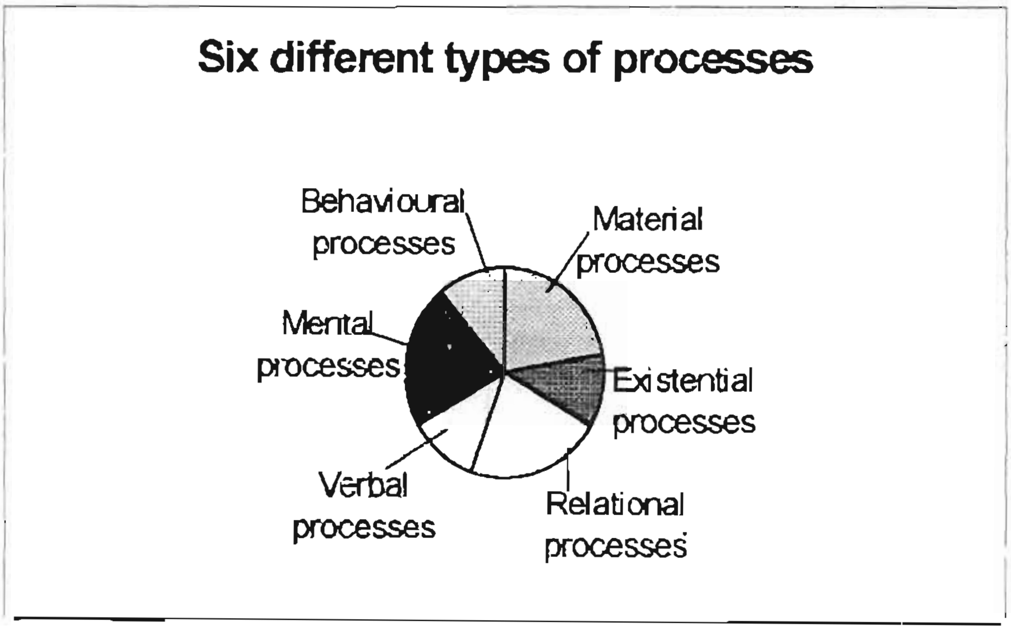
These embedded clauses are regarded as part of the nominal group or prepositional phrase in which they are included, and are thus viewed as non-ranking clauses. Their processes and participants are thus not included in the analysis in their own right but only as part of the group in which they are included. Embedded clauses are a striking feature of all texts considered in this study except those for children.

3.2.3 The Experiential/Ideational metafunction

The experiential metafunction reflects meaning in the sense of content rather than in the sense of writer's purpose. It concerns the way in which the clause represents patterns of experience (Halliday 1994:106). Through experiential meaning the writer describes events and things in the external world, as well as the internal world of thoughts, beliefs and feelings (Thompson, 1996:76). From the experiential perspective, the clause as a whole is called a process, but more narrowly, the term process refers to the verbal group (Bloor and Bloor 1995:110). Nominal groups are referred to as participants, and prepositional groups as circumstances.

Processes are of three main types: material processes (happening and doing in the real outer world), mental processes (thinking and feeling in our consciousness and imagination) and relational processes (classifying and identifying). There are three further types on the borders of these three main types. These are, firstly, those with features of both material and mental processes, the Behavioural processes (the acting out of consciousness); secondly, there are processes intermediate between mental and relational processes, the verbal processes (saying and meaning); and thirdly, there are those between relational and material processes, the existential processes (existing). Following Halliday (1994) these six types of process are illustrated in the figure below. Each of the six types of process has specific participants associated with it. The nominal groups associated with each process are called participants. Any prepositional groups included in the clause are called circumstances.

Each type of process is associated with distinct participants (realised as nominal groups) and with certain types of circumstance (realised as prepositional groups). I consider each process and its participants, in turn, below.



Material Processes

Material processes usually deal with and represent happenings in the physical world. The participants associated with material processes are the Actor and the Goal.

5

A huge asteroid	crashed	into the Earth	at the end of the Cretaceous Period.
actor	Material process	goal	Circumstance: time

Sometimes there is no goal. This is referred to as the "middle voice" (one participant) (Gerot and Wignell 1994:57):

6

The world's climate	could have cooled	over millions of years
Actor	Material process	Circumstance: time

For passive processes:

7 The rock on the Earth's surface | is formed | in layers.

The rock on the Earth's surface	is formed	in layers.
goal	Material process	Circumstance: manner

Thus material processes minimally have a verbal group and a participant, which may be either actor or goal. I now consider the second main type of process, the mental process.

Mental Processes

Mental processes give us an insight into what the human participants are thinking. The participants associated with mental processes are the Sensor and the Phenomenon.

8

We	favour	extraterrestrial causes.
sensor	Mental process: affection	phenomenon

Mental processes can be of three types: affection (e.g. 'we favour extraterrestrial causes'), perception (e.g. 'We could hear it coming') or cognition (e.g. 'Scientists think').

Mental processes of cognition are unusual in that they can project the idea that is being thought. This idea is projected as a clause in its own right.

9a

Scientists	now	think
sensor	circumstance: time	mental: cognition

9b

an asteroid	hit	Earth	at the end of the Cretaceous period
actor	Material process	goal	circumstance: location: time

Impersonal projections are not regarded by Halliday (1994:271) as real projections but as a way of turning a proposition into a fact. They are therefore not analysed as separate clauses in their own right:

10

It	seemed	that extinctions and impact should be random in time
phenomenon	mental: cognition	phenomenon: fact

Facts are embedded projections where there is no sensor (or sayer) present (Thompson 1996:209). They are construed as having already been established, even though they may not necessarily have been thought (or said). As in clause 10 above, a fact (in this case 'that extinctions and impact should be random in time') functions as a participant: the phenomenon, while 'It' is not really a functioning participant in the clause but just a placeholder for the fact. In the next section I consider the third main type of processes, relational processes.

Relational Processes

Relational processes set up relationships between two concepts, commonly a relationship of equality. They are of two types. They either assign an attribute to something (attributive process) or they assign an identity to something (identifying process). They are used in classification and are thus very common in science texts. Most relational processes are realised in the verb 'to be'.

11	If	the Lazarus effect	is	strong	for a particular event,
		Carrier	Attributive process	attribute	Circumstance: contingency: condition

Except in literary or in other unusual cases (see clause 12 below) for emphasis, attributive processes are not reversible.

12	Less certain	is	the role [[that other factors played in these events]]
	attribute	Attributive process	Carrier (with embedded clause)

Identifying clauses, by contrast, are reversible. Clauses 13 and 14 below demonstrate this reversibility. The previous clause is included in this example to make it clear that 'meteorite impact' is Given in clauses 13 and 14 while 'the Yucatán area of Mexico' is New:

The huge impact of a meteorite would have caused earthquakes and tidal waves.

13	The Yucatán area of Mexico	may have been	the site of the meteorite impact.
	Identifier/Token	Identifying process	Identified/Value

14	The site of the meteorite impact	may have been	the Yucatán area of Mexico
	Identified/Value	Identifying process	Identifier/Token

The Identified is distinguished from the Identifier in that the Identified is Given information while the Identifier is New. Thompson (1996:92) says that "the form which is already 'on the table' fills the role of identified while the newly introduced form fills that of identifier". Token is distinguished from Value in that the more general category is called the Value, while the specific embodiment is called the Token (Thompson 1996:90). When the clause is in the active voice the subject is also the token (Halliday 1994:124). In the above example, clause 13 is in the active voice while clause 14 is in the passive. Because the issue of active or passive voice is difficult to decide with the verb 'to be', the verb 'constitute' in brackets is substituted in this case:

> *The Yucatán area of Mexico may have been (may have constituted) the site of the meteorite impact.* (Active voice).
> *The site of the meteorite impact may have been (may have been constituted by) the Yucatán area of Mexico* (Passive voice).

An analysis of Value and Token is useful because it reveals what values the writer uses to measure the tokens that the text deals with (Thompson 1996:91).

15	The fossil record	shows	that not all extinctions are "normal."
	Identified/ Token	Identifying process	Identifier/ Value

16	That not all extinctions are "normal"	is shown	in the fossil record
	Identifier/ Value	Identifying process	Identified/ Token

Facts (embedded 'projections') in relational processes function as participants and are not projected by the process (Halliday 1994:271).

17	Like other samples of rock from that era,	it	showed
	circumstance: matter: comparison	Identified Token	identifying

17 cont.	that the creatures alive during the late Cretaceous period had, by geological time scales, suddenly disappeared.
	Identifier (embedded clause)

Most identifying processes are realised in the verb 'to be'. Another fairly common identifying process is realised in verbs signalling cause (e.g. *Such a global dust cloud **would result** in the total blockage of sunlight*) or proof (e.g. *The fossil record **shows** that* *not all extinctions are normal*). Because science texts describe, classify and explain, relational processes form a large proportion of processes in science texts, making them of particular interest in this study.

Behavioural Processes

Behavioural processes can be physiological processes (like smile) or near mental processes (like worry, listen or look). There are very few of them in the data in this study.

18 Richard Muller, like a seer divining entrails, scrutinises the new batch of video recordings.

Richard Muller,	like a seer divining entrails,	scrutinises	the new batch of video recordings.
Behaver	Circumstance: manner	Behavioural process	Matter

Verbal processes

Like mental processes, verbal processes give us an insight into the minds of the human participants. They also assign responsibility for what is said. Like cognitive mental processes, verbal processes project the words that are said.

19 a

Raup and Sepkoski	suggested
Sayer	Verbal process

19b

that	the periodicity	reflects	a recurrent event
	identified	Identifying process	identifier

As explained in the discussion of mental processes, the exception to this is impersonal projections such as the one below, which are not really projections but a way of turning a fact into a clause (Halliday 1994:271):

20

It	is maintained	that the Earth was hit by an extra-terrestrial body
verbiage	Verbal process	verbiage

Existential Processes

Existential processes indicate that something exists or happens (Halliday 1994:142). They usually start with 'There' (which has no representational function but is just a dummy subject), and use the verb 'to be'. They are not common in the texts in this study.

21

There	are	high levels of iridium	in the rock [[that contains the last dinosaur fossils.]]
	Existential Process	existent: entity	circumstantial: place

Circumstances

Halliday (1994:158) notes that some circumstances can be viewed as minor processes (e.g. the delay was because of a strike ~ was caused by a strike). Often they function as participants (Halliday 1994:159). An example is 'He sent a message *to him*', where 'him' is the goal rather than a circumstance. There are nine different circumstantial functions: location (time or place), extent (distance or duration), manner, cause, contingency, accompaniment, role, matter, and angle. Most circumstances in the texts in this study are circumstances of location (time and place) and extent (duration), reflecting the concern of the texts to show when mass extinctions have happened in the history of the Earth, and how long they lasted.

22

Sixty-six million years ago,	the dinosaurs	died out.
Circumstance: location: *time*	Actor	Material process

23

Possible evidence	has been found	*in Central America*	*in Yucatán.*
Goal	Material process	Circumstance: location: *place*	Circumstance: location: *place*

24

Diversity losses	are spread	*over hundreds of thousands to millions of years.*
Range	Material process	Circumstance: extent: *duration*

25

Slowly	the air	grew	colder
circumstance: *manner*	carrier	attributive	attribute

26

The dinosaurs	died	*because of the radiation coming from outer space*
actor	material	circumstance: reason: *cause*

27

In some cases, as with ocean plankton,	this number	climbed	as high as 98%.
circumstance: *contingency*: condition	carrier	attributive	attribute

28 Life on Earth did not end *with the death of the dinosaurs.*

Life on Earth	did not end	*with the death of the dinosaurs.*
actor	material	circumstance: *accompaniment*

29 The impetus came *in the form of an analysis of stratigraphic data on fossil marine animals*

The impetus	came	*in the form of an analysis of stratigraphic data on fossil marine animals*
actor	material	circumstance: *role*: guise

30 Walter Alvarez was seeking clues *to continental drift.*

Walter Alvarez	was seeking	clues	*to continental drift.*
Actor	material	goal	circumstance: *matter*

31 Gubbio is an appealing site *to geologists and palaeontologists*

Gubbio	is	an appealing site	*to geologists and palaeontologists*
Carrier	attributive	attribute	circumstance: *angle*

An examination of the experiential/ideational metafunction is called a transitivity analysis. It is useful because the processes that the writer/speaker uses to represent the world give us an insight into how the writer/speaker views the world. For example the text by Duff in my study uses material processes (usually used to realise meanings in the physical world) to talk about concepts (which would usually be realised by relational processes). The same topic is dealt with in other texts mainly in terms of the real physical world. So it is clear that Duff views even the physical world as existing partly in the realm of ideas. Such construal of meaning through grammatical resources other than those that we would expect to be used is known in Systemic Grammar as grammatical metaphor.

Grammatical Metaphor

Grammatical metaphor occurs when meanings are not realised through the grammatical resources through which we would expect them to be realised. Halliday (1994) refers to these expected ways of realising meaning as 'congruent' realisations. People, places and things are congruently expressed as nouns (rather than epithets or processes). Actions are congruently expressed as verbs (rather than things or epithets). Logical relations of time and consequence are congruently expressed as conjunctions (rather than phrasal processes - such as due to, or processes or things) and quality is realised as epithets (rather than adjunct, thing or process) (Martin 1993:239). A very common form of grammatical metaphor in scientific texts is nominalisation, in which a process or quality is expressed as a thing. Nominalisation can serve to avoid the fact that some agent is involved. For example in the following clause who has attended to the boundary?

32 *Much attention has been paid to the Cretaceous/Tertiary (K/T) boundary.*

Grammatical metaphor enables reasoning within rather than between clauses:

33

Examination of clays	has shown	some chemical and mineralogical *peculiarities.*
Identified token	Identifying process	Identifier value

The more congruent realisation of this clause would involve more than one clause:

When people examined the clays, // they noticed that the chemicals and minerals in the clays were peculiar.

Or:

When the clays were examined, // it was noticed that the chemicals and minerals in the clays were peculiar.

In scientific writing nominalisation allows the development of technical terms by allowing processes to be placed in relation to each other as token and value (Martin 1993:227). In the following example we see how an attribute (extinct) becomes a thing (extinction). Then a token (the one in which the dinosaurs perished) can be given a value (the best known of these mass extinctions).

34 Rare catastrophic events in the past have caused large numbers of species to become

extinct suddenly. These events are called	*mass extinctions.*	The best known of these
epithet	*Nominal group*	*Value*

mass extinctions is	the one in which the dinosaurs perished some 65 million years ago.
Value	*Token*

Halliday (1987:78) points out that nominalisation backgrounds information. He compares 'technology has improved' (this is the message) with 'improvements in technology' (the writer has backgrounded the improvements and expects the reader to take them for granted. The message is in what follows this nominalisation).

This section (3.2.3) has examined ideational meaning in clauses by looking at participants in the clause and the six different kinds of process (material, mental, relational, behavioural, verbal and existential) associated with them. It has also looked at the different kinds of circumstances found in clauses. The section has in addition given some attention to grammatical metaphor, the phenomenon in which meaning is realised grammatically in ways other than expected.

3.2.4 The Textual metafunction

The third component of meaning in language, the Textual metafunction, is concerned with how the different parts of the message fit into the entire text or conversation (Thompson 1996:117). Writers and speakers signal to their readers or listeners how what is being said at the moment fits in with what has been said before or what is to come. Writers and speakers have a number of resources for doing this. Those most prominent in my analysis in chapter 4 are: what is regarded as Thematic information and its patterning from clause to clause, and Conjunctive relations between clauses. This section (i.e. 3.2.5) will consider each of these in turn.

3.2.4.1 Theme and rheme

Every clause consists of two parts: the Theme, which Halliday (1994:36) characterises as the "element which serves as point of departure for the message", and the rest of the clause, called the Rheme. In English the function of Theme is realised by first position in the clause. Theme "orients the listener/reader to the message" (Fries 1995:318) and provides a framework for its interpretation. The rheme is "the unmarked location of New information" (Fries 1995:335). It is where we find newsworthy information to which we should pay attention.

35	The Yucatán area of Mexico	may have been the site of the meteorite impact.
	theme	rheme

Because the theme is the starting point of the message, in choosing to make 'the Yucatán area of Mexico' thematic, the writer or speaker is saying 'I'll tell you about the Yucatán area of Mexico' (Halliday 1994:38). Had the order been turned around:

36	The site of the meteorite impact	may have been the Yucatán area of Mexico.
	theme	rheme

The writer or speaker would be saying 'I'll tell you about the site of the meteorite impact'.

Most commonly the theme is the subject of the sentence, so this is regarded as the **unmarked** form in English. A marked form is the less expected form and usually serves as a signal to the reader/listener to notice the marked feature in some way. For example it can signal a change in the framework for interpretation of the text. A theme that coincides with Actor/Sayer/Sensor (see section 3.2.3 above) is the more usual and thus unmarked form. Different cases will be more or less marked. Cases where the Goal/Verbiage/ /Phenomenon are in thematic position (accompanied by passive verbs) are slightly marked. Such cases can function to foreground the Goal/Verbiage/Phenomenon (signalling that what the writer is telling us about is the goal, not the actor).

37 The case for mass extinctions by catastrophe has been developed by the American writer S.J. Gould.

Slightly marked theme	rheme
goal	

Alternatively, placing Goal/Verbiage/Phenomenon in thematic position can function to leave out the Actor/Sayer/Sensor completely (signalling that who performed the action is irrelevant, or perhaps that the writer wants to conceal who did the action). Passive verbs are fairly common in scientific writing, which accounts for my assessment of them as only slightly marked:

38 An impressive body of evidence has been amassed.

Slightly marked theme	rheme
goal	

A more marked construction is the positioning of a circumstantial element in thematic position.

39 At the end of the age of the dinosaurs, an asteroid streaked out of space.

Marked theme	Rheme
Circumstance: time	

Many of the texts in this study are structured by means of circumstances of time or place in marked thematic position. Thompson (1996:141) notes that choice of circumstance as marked theme often functions to specify or change the framework of the interpretation of the following clause. Another marked theme that fulfils this function is the 'heavy' (unusually long) Subject theme (Thompson 1996:141) which is quite common in the texts in this study:

40 The progressive loss of sampling area [[produced by regressing seas]], [[combined with the erosion and destruction of previously deposited strata,]]

'heavy' theme
Subject
Actor

40 cont. can smear last appearances of species backwards in time.

rheme

So far all the examples have been limited to experiential or topical themes. Besides experiential elements, the theme may also contain interpersonal and textual elements. Interpersonal themes may be modal adjuncts, finites or Wh-interrogatives (Gerot and Wignell 1993:113).

41

Curiously,	none of these multiple horizons	appears to correspond to known extinction horizons.
Interpersonal theme	Topical theme	rheme
Modal adjunct		

42

Why		didn't the dinosaurs get used to the cold?
Interpersonal theme	Topical theme	rheme
Wh-interrogative		

Textual themes may be conjunctions (like 'and' or 'but'), which usually function to connect the clause to a previous part of the clause complex. Or they may be conjunctive adjuncts (like 'On the other hand), which join the clause to text outside the clause complex (Gerot and Wignell 1993:113). The initial position is not the obligatory positioning of conjunctive adjuncts, and this choice thus serves as a marked choice.

43 a

But	dinosaurs	laid a lot of eggs.
Textual theme	Topical theme	rheme

43 b

and	their eggs	were big.
Textual theme	Topical theme	rheme

44

On the other hand,	iridium-enrichment horizons	have been discovered.
Textual theme	Topical theme	rheme

A dependant clause (β clause) that comes first is the theme for the whole clause complex (Gerot and Wignell 1994:109). This is also a marked choice of theme, and may serve to specify or change the framework for the interpretation of what follows.

45 a

Although	the causes [of the periodicity]	are unknown
β clause as theme[1]		
Textual theme[2]	Topical theme[2]	Rheme[2]

45 b

it	is possible [[that they are related to extraterrestrial forces.]]
Rheme[1]	
Topical theme[3]	Rheme[3]

Other marked themes that function to specify or change the framework for the interpretation of what follows are predicated themes (Thompson 1996:141) and thematised comment. Both of these are rare in the texts in this study.

46

It is a wonder	that [[anything survived at all.]]
Predicated theme	rheme

47

It is entirely reasonable	to propose that such an event has taken place in the past
Thematised comment	rheme

Daneš (1974) found a number of types of thematic progression:

1 Linear thematic progression

$$
\begin{array}{lllll}
T_1 & \rightarrow & R_1 & & \\
 & & \downarrow & & \\
 & & T_2\ (=R_1) & \rightarrow & R_2 \\
 & & & & \downarrow \\
 & & & & T_3\ (=R_2) \rightarrow R_3
\end{array}
$$

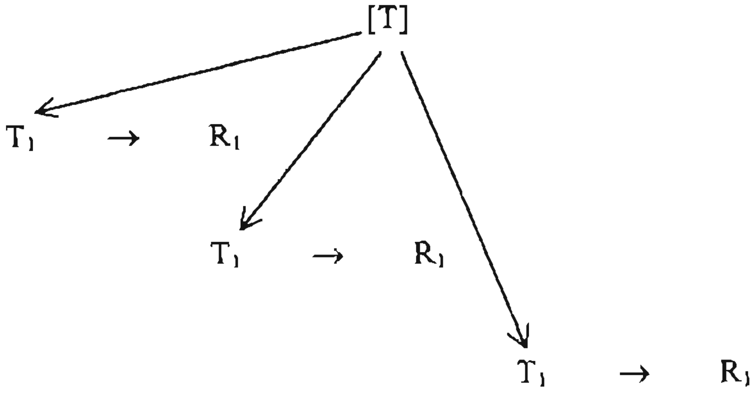
This thematic pattern signals progression of what the text is about (Thompson 1996.141).

2. Theme iteration

$$
\begin{array}{lll}
T_1 & \rightarrow & R_1 \\
\downarrow & & \\
T_1 & \rightarrow & R_1 \\
\downarrow & & \\
T_1 & \rightarrow & R_1
\end{array}
$$

This thematic pattern signals maintenance of what the text is about (Thompson 1996:141).

3. Progression with derived themes



According to Thompson (1996:142) changing from one type of theme to another in three successive clauses may be used to signal the boundaries of sections of the text. Writers and speakers may also signal what they consider to be important by repeatedly choosing the same element as theme.

In summary, this section has outlined how thematic development is used by writers/speakers to signal to readers/listeners how what they are saying is linked to what has already been said or will still be said. Marked themes are used by writers to signal a change in the framework for the interpretation of what follows, or to signal a boundary between one section of the text and another.

3.2.4.2 Conjunctive relations in texts

Conjunction is a second way that is important to my analysis in chapter 4 by which writers signal to readers where they are in the text. Through conjunction writers and speakers relate clauses in terms of temporal sequence, consequence (cause and effect), comparison and addition (Martin 1983:1). These relations may be explicit (a conjunction is used) or implicit (a conjunctive relationship is implied). Conjunctions may connect clauses externally (relations between events in the real world (Gerot 1995:100)) or internally (rhetorical relations within the text itself (Martin 1993: 233)). Most conjunctions can be used in both ways (Martin 1983:2). Halliday (1994:327) advises caution in the assignment of implicit conjunctions in interpreting a text, pointing out that the presence or absence of explicit conjunction is an important variable between texts. Analysis should consider what

Table 3.3 Principal conjunctive relations (van Leeuwen 1991:81, Halliday 1994:324)

- elaboration →
  - presenting →
    - Expository/explanation (that is)
    - Example (for example)
  - distilling →
    - Verifactive (in fact, actually)
    - Summative (in short)
    - Corrective (at least, or rather)
    - Particularizing (specifically)
- extension →
  - expanding →
    - Addition →
      - Positive (and)
      - Adversative (but, yet, however)
      - Negative (nor)
    - Alternative (or)
    - Replacive (instead)
  - qualifying →
    - temporal →
      - Succession (then, next)
      - Simultaneity (meanwhile, here)
      - Preceding event (previously)
      - Conclusive event (finally)
    - Comparison →
      - Positive (similarly)
      - Negative (by contrast)
    - causal →
      - Result (in consequence)
      - Reason (on account of that)
      - Purpose (for that purpose)
    - conditional →
      - Positive (in that case)
      - Negative (otherwise)
      - Concessive (nevertheless)

is being left unaccounted for by the text. For example, if we find few or no external conjunctions in a text and thus no explicit causal temporal or comparative relations, it may be that these are being realised within clauses (as grammatical metaphor) rather than between clauses (Martin 1993:235). In my analysis I therefore consider only explicit use of conjunction. The principal types of conjunctive relation are displayed in Table 3.3 above.

This section on the Textual metafunction has indicated how writers signal to their readers how different parts of a text are related to each other through the resources of theme and conjunctive relations. Theme is the starting point for the message, signalling to the reader what the message of the clause is about. Thematic development indicates to the reader how the message is developing: whether the writer is keeping to the same topic and thus maintaining the theme, or whether the writer is selecting the theme from the previous rheme and thus putting forward a progressing argument. Conjunctions relate clauses to other clauses in terms of cause, time, comparison etc.

3.2.5 The Interpersonal metafunction

This section considers the second of the three components of meaning in language, the Interpersonal metafunction. The interpersonal metafunction is usually discussed in terms of communication as an exchange, either of goods or information. This exchange is realised in clauses of different types: statement, command, question and offer. In what follows, I briefly outline this distinction. However, the clauses in my study are almost exclusively statements ('offers' of information rather than goods), and in my exploration of interpersonal meaning in the texts in the study I rely on a number of other features. These include status, contact, affect, modality, hedging, and evaluation.

These features allow an examination of the ways that social relations are realised, the roles that the writer or speaker takes on and constructs for the reader or listener, and what people think about the people they are writing/speaking to and the things, events or ideas they are writing/expressing. A consideration of *status* allows a comparison of the relative status of the speaker/writer and listener/reader (Gerot 1995:104). Status can range from equal to unequal/ hierarchical. *Contact* refers to how familiar the speaker/writer and listener/reader are with one another, and what degree of solidarity is shown between them. *Affect* refers to whether the speaker/writer and listener/reader like or dislike each other and what is being discussed. Affect is realised in attitudinal lexis such as qualitative attributes, interpersonal epithets, verbal/mental affective processes, and formal/colloquial language. Another means by which interpersonal meaning is communicated is through *modality*. This refers to how certain the speaker/writer is of the truth of what s/he is saying. Next, *hedging* refers to the ways that writers use modality and other resources (such as attributions such as '*they suggested* that...' or approximators such as '*about* 50 km/hour'). Writers/speakers hedge what they say not only to signal how certain they are of what they are saying, but also to shield themselves from responsibility for what is said and to show deference to the reader. Through *evaluation* writers/speakers indicate where they think an entity, event or concept falls on a variety of scales, such as good/bad. Modality, hedging, and evaluation in particular are key features in my analysis of interpersonal meaning in this study, and I consider them at greater length below. However, first I outline the notion of the clause as exchange and the role of the mood element (subject and finite) in realising this.

3.2.5.1 The clause as exchange

The interpersonal metafunction reflects communication as an exchange, either of goods and services, or of information. The writer/speaker can offer goods and services ('offer') or information ('statement'). Alternatively the speaker can demand goods and services ('command') or information ('question'). The texts in this study consist overwhelmingly of statements, expressed by declarative clauses:

48

The rock on the Earth's surface	is	formed in layers.
subject	finite	
Mood element		

There are also a limited number of questions, expressed by interrogative clauses:

49

Did	caterpillars	eat	all the vegetation?
finite	subject		
Mood element			

In only two cases are there commands, expressed by imperative clauses, and there are no offers.

50

It	should	be noted	that the composite curve in Fig 4 rises to a peak.
subject	Finite		
Mood element			

The mood element, consisting of the subject and the finite, is important in considering the interpersonal metafunction. The subject is important because it "expresses the entity that the speaker wants to make responsible for the validity of the proposition being advanced in the clause" (Thompson 1996:45). The finite on the other hand is important according to Thompson (1996:45), because it indicates tense (for what time relative to the time of speaking was the proposition valid?), polarity (is the proposition positive or negative?) and modality (how valid is the proposition?) So it is the finite that makes the validity of the proposition negotiable.

The finite expresses tense:

51 Asteroids are lumps of rock in orbit round the sun.

Asteroids	are	lumps of rock in orbit round the sun.
subject	finite	
Mood element		

52 The dinosaurs' eggs were big.

The dinosaurs' eggs	were	big.
subject	finite	
Mood element		

53 These reptiles had been dying out for some time during the Cretaceous.

These reptiles	had	been dying out for some time during the Cretaceous.
subject	finite	
Mood element		

The finite expresses negative and positive polarity. Thompson (1996:56) notes that positive polarity is the unmarked form, with the negative having a 'not' added:

54 Crocodiles, frogs, birds and mammals did not die out.

Crocodiles, frogs, birds and mammals	did not	die out.
subject	finite	

3.2.5.2 Modality

Very revealing of interpersonal meaning in this study is the category of modality, realised in the finite in modal verbs:

55 This change of climate may have taken thousands or millions of years.

This change of climate	may	have taken thousands or millions of years.
Subject	Modal finite	

Modal finites include the following (Halliday 1994:76):

Low modality	Median modality	High modality
can, may, could, might	would, should	must, ought to, need, has to, had to

Polarity is the choice between yes and no, while modality is the intermediate stages between yes and no. (Halliday 1994). When we consider exchange of information as in statements and questions, we find two kinds of modality: degrees of probability (possible, probable, certain) and degrees of usuality (sometimes, usually, always). Modality thus gives an insight into the writer's assessment of the truth-value or credibility of his/her statements. Modality may be achieved through modal verbs, through modal adjuncts and through a number of other means. In what follows I expand on each of these in turn. Firstly, modal adjuncts may be of two types: comment adjuncts like 'unfortunately', or 'interestingly' (which comment on the whole clause), and mood adjuncts like 'generally' or 'perhaps', which are related to the finite in that they express meanings to do with tense, modality and polarity (Thompson 1996:54).

56

Curiously,	none of these multiple horizons	appears	to correspond to known extinction horizons.
Comment adjunct	subject	finite	

There are very few comment adjuncts in the texts analysed in my study but a large number of mood adjuncts. This may indicate that comment adjuncts are more overtly subjective than are mood adjuncts and are thus less likely to be used in texts that aim to be/appear objective.

57

Certainly	such a climatic upheaval	would	have a major effect on the biosphere.
Mood Adjunct	subject	finite	

58

Perhaps	peckish mammals	ate	their eggs.
Mood Adjunct: probability	subject	finite	

Halliday (1994:82) notes that mood adjuncts may express modality and polarity (polarity, probability, usuality, readiness, obligation), temporality (time, typicality), and mood (obviousness, intensity, degree).

59

But	we	can	only	guess why this happened.
	subject	finite	modal adjunct: intensity	

Other means of expressing modality include mental and verbal processes (I think, I suggest) or nominalisations of these (the belief that...), nominalisations of modal adjuncts (e.g. the possibility that...), adjectives (possible evidence is ...), impersonal 'projections' (it is possible that ...). I provide examples of each of these in examples 47 to 50 below.

Mental process expressing modality:

60 Some scientists *think* that a giant meteorite fell from space and hit our planet

subject	finite

Nominalisation of modal adjuncts:

61 The *possibility* that the solar 'constant' varies is interesting, but difficult to demonstrate

Subject	Finite

Modal adjective:

62 *Possible* evidence for this has been found in Central America in Yucatán.

Subject	finite

Impersonal 'projections' in relational clauses:

63

It	is	*possible*	that both groups of scientists are right
Subject→	finite		subject continued

3.2.5.3 Hedging

Using modality and a number of other resources, writers and speakers *hedge* to signal how certain they are of what they are saying, to shield themselves from responsibility for what is said and to show deference to the reader. An analysis of hedging thus gives a good deal of insight into the relative status of writer and reader, as well as the writer's assessment of the reliability of what they say. (Hyland 1996c:439) identifies two main types of hedging: content-oriented hedging, and reader-oriented hedging. He refines the content hedges into three types: attribute hedges, reliability hedges, and writer-oriented hedges. Examples of each type are given in Table 3.1 below.

Table 3.1: Kinds of hedge

Kinds of hedge	Examples of each kind from the data
Attribute hedges specify the extent to which a term accurately describes the reported phenomenon. They are usually 'degree of precision' adverbs.	It was *at least partly* responsible for the mass extinction *About* 250 million years ago, *about* 80% of existing species disappeared in a single extinction event.
Reliability hedges convey the writer's assessment of the certainty of the proposition. They are motivated by the writer's desire to convey explicitly an assessment of propositional validity. Hyland (1996c:441).	This number *may have climbed* as high as 98%. These *could have blotted out* the sun's light
Writer-oriented hedges conceal writer viewpoint and allow the writer to avoid responsibility for what is said.	A series of smaller impacts, *is argued* to have produced the sequential extinctions! *Jablonski (1986a) noted* //that the Lazarus effect appears worst for the Late Permian event.
Reader-oriented hedges can hedge statements that are face-threatening to readers by acknowledging personal responsibility or they can show solidarity with readers by inviting reader involvement	*We* favour extraterrestrial causes. *A first question* is whether **we** are seeing the effects of a purely biological phenomenon.

3.2.5.4 Evaluation

Because of the ideological necessity in science to present propositions as objective, writers are constrained in their use of attitudinal lexis, which is a common way of indicating the writer's opinion and values. Values in science are therefore communicated very subtly, making invaluable an analysis of evaluation, which considers each clause in terms of parameters such as certainty and relevance. Thompson and Hunston (2000:3) point out that some writers have distinguished expressions of opinion about entities (referred to as modality) and expressions of opinion about propositions (referred to variously as attitudinal meaning, appraisal, and evaluation). I follow their preference for the use of the term 'evaluation' as a combined term referring to writer opinion about both entities and propositions.

According to Thompson and Hunston (2000:21), we recognise evaluation as language that is comparative (adjectives and adverbs), subjective (modals, some adjectives, adverbs, nouns and verbs, marked clause structures such as clauses beginning with *it* and *there*) and value laden (lexical items and the indication of goal achievement). Parameters of evaluation are: good/bad, expectedness, certainty, importance and relevance. Particular parameters are prioritised depending on the discourse (Thompson and Hunston 2000:24). Analysis of texts in this study indicates that in scientific discourse certainty is prioritised.

Because I follow Hunston (1994:193) closely in my analysis of evaluation it is necessary to outline in some detail the categories she uses. To illuminate evaluation, Hunston uses the categories of *Status* and *Value*. *Status* (Hunston 1994:218) is evaluated on the scale of certain-uncertain, and is attached to every clause. It is identified by writer activity, the source of the proposition, modifications, and the resulting place of the clause on the certainty scale. Writer activity includes 'state fact', 'interpret results', 'assess', 'narrate event', 'hypothesise', 'recommend', 'assert status', 'describe figure'. Status is given to each clause by the writer. It refers to the alignment of statement and world, which constrains the reader's reaction and evaluation of a statement. Status reifies each statement (makes it into a "thing" i.e. an hypothesis, assumption, fact, etc.) (Hunston 2000:186). Statement types can be:

- Statement types
  - Informing
    - World-creating
      - Assumption
      - Hypothetical
      - Recommendation
    - World-reflecting
      - Fact/event (open to verification)
      - Interpretation/hypothesis
      - Assessment (not open to verification)
  - Focusing (statements describing the text itself)

The source of the proposition may be received knowledge, data, the writers, or the text. Hunston (2000) distinguishes between attribution (of language to someone else) and averral (where the writer speaks for him/herself.) Averral can be modified by modals, or vague language and attribution can be modified by choice of attributing verb or noun. The resulting place of the clause on the certainty scale ranges from known, certain, probable, possible, unlikely, untrue to unknown.

Value, which is attached to some items only (Hunston 1994:196), evaluates items on the scale of good-bad in terms of the achievement of the goals of the activity. An item with the status of *event* may be positively evaluated (Hunston 1993:53) as having accuracy (freedom from distortion, artefact etc; comprehensiveness), consistency (fit to other methods), verity (closeness to non-lab conditions), simplicity (ease of performance), usefulness (goal-achieving), or independence (fit to observation, not theory).

An item with the status of *result* may be positively evaluated as having reasonableness (fit to expectation, other facts, projections), reliability (certainty), consistency (fit to data, repeatability), supportiveness (fit to theory), usefulness (ability to evaluate theory), importance (relevance, significance). An item with the status of *hypothesis* or *interpretation* may be positively evaluated as having accuracy (fit to data), applicability (fit to range of data), usefulness (explicatory power), reasonableness (fit to expectation, other knowledge)

The example below indicates how the writer of the following extract from the text in my study taken from Scientific American, evaluates what s/he is saying:

> [32a]*The* Alvarez group proposed // [32b]that the extinctions and the iridium layer had a common cause: the impact of an extraterrestrial object, [[probably an asteroid about 10 kilometers in diameter]]. // [33]Since then the finding [[that an iridium anomaly exists at many other sites around the world and that the iridium-rich clay also contains minerals apparently altered by heat and shock]] have bolstered the case for a Cretaceous impact. //*

Table 3.2 Illustration of Hunston's approach to evaluation

Clause	Activity	Source	Modification	Certainty	value
32a*	project				
32b	hypothesis	Alvarez group	proposed, probably	probable	**Hypothesis**
33	result	unspecified Research Articles	apparently, have bolstered the case	probable	+ *accuracy*

* As I explain in section 4 0.1 I use the convention superscripts in numbering the clauses of the texts in my study.

The popular journal articles in this study share some of the values identified by Hunston (1993) as important in science research articles, and also reveal other values such as being current, famous or controversial. This example from the Mail and Guardian text (see section 4.4) indicates that a topic being current or new is positively evaluated

> [1a]*Discovering the fate of dinosaurs is the hot topic in palaeontology right now -* [1b]*at least, it is among those [[who don't see it as another source of trivialisation of their subject.]]*

Clause	Activity	Source	Modification	Certainty	value
1a	assess	writer		certain	+ current

Hoey (2000:32) points out that evaluation can be buried inside clauses, i.e. inside nominal groups or circumstances, making questioning of the evaluation more difficult for readers. An example from the above section of the Mail and Guardian extract buries the writer's evaluation of palaeontology as trivial inside a circumstance of location, implying that it is unnamed 'those' who have made the evaluation.

1b	at least,	it	is	among those [[who don't see it as another source of trivialisation of their subject.]]
				Circumstance: location: place (abstract space)

To sum up: in my discussion of the interpersonal metafunction above, I have focused on the categories of modality, hedging and evaluation, as these are the most revealing of interpersonal meaning in my analysis in chapter 4. The study concerns written texts, in which the authors are at pains to create an impression of objectivity through omission of human participants (the research articles and textbooks in particular). Because the texts are in the written mode and because the writers of most of them try to create an impression of objectivity, the categories of hedging and evaluation, which operate at the grammatical level and are subtler than attitudinal lexis, are invaluable in illuminating interpersonal meaning in my study.

In what follows I turn from analysis of verbal to analysis of visual meaning in texts.

3.2.6 Analysis of illustrations

In my analysis of the images associated with the texts in this study I rely on Kress and van Leuwen (1996). Their system of analysis of images is based on Systemic Functional Grammar (Kress and van Leuwen 1996:40). As in Systemic Functional Grammar, Kress and van Leuwen (1996) consider three metafunctions: ideational (what objects or events are depicted), interpersonal (what relations are projected between the depicted participants and viewer, and between the producer and viewer) and textual (what the composition of the image means). I provide a brief summary of Kress and van Leeuwen's (1996) system below.

3.2.6.1 The Ideational/Experiential metafunction in illustrations

As in the textual grammar described earlier, the ideational metafunction reflects meaning in the sense of content. In this section I consider the kinds of ideational meaning found in illustrations in my study: narrative, classificatory, and analytical meaning. Kress and van Leeuwen (1996:56) divide expression of ideational meaning in illustrations into Narrative processes and conceptual processes. Narrative processes have a vector, an element that forms an oblique line. The vector often joins two participants: the actor, from whom the vector emanates, and the goal, at which the vector is directed. As in text the goal may not always be present in the image (called a non-transactional action) and sometimes the actor is merged with the vector. Sometimes the vector is formed by the direction of the glance of a participant. The top photograph from Time on page 30 of the appendix article depicts Luis and Walter Alvarez smiling (presumably) at the photographer. The photographer and the viewer become the object of their friendliness.

The second process by which ideational meaning is expressed in images is through conceptual processes, represented in this study by classificatory, and analytical processes. In the classificatory processes in this study, the participants are distributed across the picture space and are equal in size (for example the top right image in *Prehistoric Life* (see appendix) comparing animals that died and animals that survived the Cretaceous extinction).

A good many of the images in this study are analytical, reflecting the fact that the texts are scientific. In analytical processes there is no vector. The image depicts two types of participant: the carrier (whole) and the attributes (parts). Examples are the many photographs or drawings of impact craters in this study, with the landscape as carrier and the crater as attribute.

Topological analytical processes (Kress and van Leeuwen 1996:101) accurately represent the logical relations between participants, but not the actual size or distance between them. An example is found in Time (page 32 in the appendix) which shows the Nemesis theory: how the proposed companion star Nemesis disrupts the Oort cloud and sends comets into the solar system where they hit earth.

Graphs are classified as spatio-temporal analytical images. They are highly abstract analytical structures. Interestingly, the only example in my data is in the research article in my study by Raup and Sepkoski (see page 5 of the appendix).

An example of a temporal analytical process (Kress and van Leeuwen 1996:95) is found in Time (see page 30 of the appendix). This depicts a geological timeline of the last 250 million years with mass extinctions occuring approximately every 26 million years.

In summary, Kress and van Leeuven's (1996) application of Systemic Functional Grammar to images enables a consideration of whether an image is narrative, classificatory or analytical, and what each of these imply for the overall meaning of the text.

3.2.6.2 The Interpersonal metafunction in illustrations

As noted earlier, interpersonal meaning refers to the ways that social relations are realised, and what roles the participants take on. In this section I consider the participants, the distance between them, the attitude of the projected viewer to the image, and expression of modality. Kress and van Leeuwen (1996:119) note that there are 2 types of participants that need to be taken into account in images. These are the represented participants (within the image) and the interactive participants (the producer and receiver).

In considering relations between the represented and interactive participants Kress and van Leeuwen (1996:121) divide images into those where the represented participants look directly at the viewer (these images demand a social response from viewers) or those where the represented participants do not 'make eye contact' with the viewer. These they characterise as offering information to viewers. Diagrams and maps are offer images; they offer objective dispassionate knowledge, (Kress and van Leeuwen 1996:126). Examples of such offer images are found in most of the texts analysed in this study (e.g. the map in *Prehistoric Life*, appendix page 46, analysed in section 4.5.).

Another important element in creating interpersonal meaning is social distance between represented participants and viewer. This is realised through choice between close-up, medium or long shot. For example, in the Time article in this study, most photographs of people are in medium shot, between what Kress and van Leeuwen (1996:130) call far personal distance and social distance, eliciting our sympathy, and indicating a positive attitude to scientists as found in the written text In depicting Walter and Luis Alvarez (Time page 30 of the appendix) in close up personal distance, the writer/producer asks us to sympathise with and 'befriend' these people, the originators of the Impact hypothesis, which the writer supports in the written text.

Subjective or objective attitude.

The angle at which the viewer sees the subject matter of the image contributes to whether the producer of the image intends the viewer to see him/herself as subjectively involved with the subject matter or as objectively observing it. Whether the angle from which the photograph or drawing has been taken is frontal or oblique contributes to whether the viewer is involved or detached in his/her view of the participants. Participants who are seen obliquely or are turned away are depicted as "not of our world", while those depicted frontally are represented as being people we are involved with and who are "part of our world". Thus in the Time article the many photographs of the scientists turned away from the camera (e.g. Time page 32 of the appendix) represent the scientists as not really 'of our world' i.e. the world of the writer and the viewer/reader. They are involved in the world of science, and construed as Other. The only scientists treated as 'like us' are Walter and Luis Alvarez, who we see in frontal close-up, demanding the social response of friendliness (Time upper photograph on page 30 of the appendix).

Similarly, high angles make the producer of the image or viewer more powerful. For example the dead dinosaur (page 37 of the appendix) in *All About Dinosaurs* is viewed from a high angle: it is dead and powerless. Low angles make the image more powerful. For example the *Liopleurodon* and the *T-rex* in the Mail and Guardian article (page 35 of the appendix) are viewed from beneath and thus signalled as powerful and menacing). In each case this allows us to see how we have been positioned by the producer of the image (Kress and van Leeuwen 1996:149).

In scientific/technical images, objectivity is usually encoded through use of a directly frontal or top-down angle (Kress and van Leeuwen 1996:149). The top-down angle is the angle of maximum power and is oriented towards 'theoretical' objective knowledge. Examples of images with this 'god-like point of view' objectivity are the photograph of the Martian moon Phobos in McGhee (appendix page 13) and the impact crater in the Scientific American article (appendix page 23). Another point of view that encodes objectivity is the cross-section (Kress and van Leeuwen 1996:150). An example is the diagram of The Nemesis Theory in the Time article (page 32 of the appendix).

Modality

Modality refers to whether an image is represented as being true. Currently, the dominant standard that we judge visual realism by is photo-realism. What is perceived as real differs with culture and changes over time. The realism of science and technology is different from 'common-sense' photographic realism. Kress and van Leewen (1996:169) speak of 'Galilean realism', as what can be known by measurement or other methods of science. So in science a line drawing without colour, texture, brightness, or perspective can be judged more real than a photograph. Kress and van Leewen (1996:170) also make the point that abstraction is valued in science. Thus whatever features are useless for the technological/scientific purposes of the image (e.g. colour, depth, background etc) are low in modality – i.e. they reduce the realism of the image.

In summary this section indicates that, as with interpersonal meaning in texts, interpersonal meaning in illustrations is very important for my analysis of ideology in texts. An analysis of interpersonal meaning in images can reveal how the producer of the image expects the reader to view the image. It can indicate what relationship the writer expects to exist between the reader and people or other subject mater depicted, and the extent to which the writer/producer expects the image to be viewed as realistic and objective.

3.2.6.3 The Textual metafunction in illustrations

As with textual meaning in written text, the producer of the image uses the textual meaning of images to signal to the viewer how the different parts of the image, or different images within a page, fit together. In this section I consider how composition of an image relates the ideational and interactive meanings of an image in two important ways. Firstly, where is a particular element placed in the image, and secondly, what Framing is created by the actual frame or dividing lines within the image? The meaning of the placement of elements in an image is of course entirely conventional, and the meanings discussed in Kress and van Leeuwen (1996) and below reflect the meaning of placement in the western tradition, where the texts in this study are firmly placed. The first meaningful feature is whether an element is on the left or right of the image, whether it is at the top, bottom or in the centre. As in the English clause, Given information is placed 'first' i.e. it is on the left of the image. New information is placed 'second' i.e. on the right of the image. For example in the Mail and Guardian article (see appendix page 35), the image of the *T-rex* (a well known and instantly recognisable element) is on the left and is therefore Given. The *Liopleurodon* on the right (an unknown dinosaur to most viewers) is New.

A further feature is whether the element is at the top or bottom of the image. Placement at the top indicates that the producer of the image regards the element as the 'Ideal', while placement at the bottom means that the producer regards the element as representing the Real. In the same Mail and Guardian article (tellingly entitled 'Why dinosaurs won't go away'), the cartoon-like *T-rex* is placed at the bottom of the page (see appendix page 35). Unframed, it has intruded into the newspaper world of the reader and is, in the view of the writer of the article, the Real image of the dinosaur. The more naturalistic *Liopleurodon*, located at the top of the page, and swimming peacefully and unseeingly through its own framed habitat, is the Ideal.

Framing separates elements from each other while lack of a frame allows connectedness. The lack of frame around the 2 images of Earth being hit by an asteroid in *DK Picturepedia* (appendix page 40) makes these 2 images primary on this double page. The black background of the page is actually the background/environment/'outer space' of these two images of Earth. The text and boxes containing other images and text are additional/ /elaborate on these two primary images.

This section has considered organisational meaning in illustrations in two different ways. Firstly the placing of an image or element in an image on the page signals whether the producer of the image regards it as Given or New, and Ideal or Real. Secondly, the framing of the image indicates the connectedness or separateness of images on a page.

3.2.7 Summary of the chapter

The topic of the texts in this study is constant with respect to field, all texts concerning what caused the extinction of the dinosaurs at the end of the Cretaceous era. My analysis of five texts in four genres (research article, textbooks, popular texts such as science journals, newsmagazines and newspapers, and finally science books for children) is provided in chapter 4, where is reference to and comparison with a further six texts, for which full analysis is not provided.

The texts in the study are subject to comprehensive discourse analysis that uses Systemic Functional Grammar as an analytical tool. This grammar, as I have mentioned before, focuses on meaning, and considers the choices made by writers in communicating their message. This makes it useful in examining the ideological content of texts. Systemic Functional Grammar considers meaning in texts in terms of two dimensions of context: context of situation (register) and context of culture (genre). Context of situation has three components of meaning: Ideational meaning (experience of the physical world), interpersonal meaning (enacting social reality), and textual meaning (organisation of the message. Images that accompany text can, as Kress and van Leeuwen (1996) demonstrate, also be analysed in terms of these three metafunctions. I, too, do so in this study, and report on my findings in the next chapter, viz. Chapter 4.

CHAPTER 4: ANALYSIS OF DATA

4.0 Introduction and overview

In this chapter I seek to provide an answer to the first two of my research questions:

1. *What distinguishes popular from academic scientific genres, and how do they relate to each other?*
2. *How does register in representative texts from each genre illuminate the ideological assumptions of each genre?*

To answer the first question, my study compares the discourse features of scientific texts in four genres. Two of these genres – the research article and textbook – are academic genres of science and have been relatively well studied. The other two genres – articles in magazines/newspapers, and children's books, – are 'popular' genres of science and have had less interest shown them. Central to this study, therefore, is a comparison of the popular with the more serious genres. The texts, as readers will recall (cf. section 3.1) are all on the same topic, namely: what caused the extinction of the dinosaurs.

In order to achieve the comparison just mentioned I have selected exemplary texts in each genre. As I explained in chapter 3 (cf. section 3.1) more than one text was analysed fully in each of the genres (except the research article genre, which has had more previous attention shown it than the other genres). However, for reasons of space and to avoid repetition, where the texts analysed in a particular genre are very similar, only one text is discussed in chapter 4. I mention other texts in the genre where there are interesting differences, in order to show the variation that appears within a particular genre. Thus I have analysed a single text in the research article genre in 4.1 (cf. appendix page 2). In 4.2 I analyse a single extract from a Geology textbook (cf. appendix page 8), making some reference to two other textbooks (cf. appendix pages 12 and 18), written with different readers in mind. In my consideration of popular scientific texts, I found greater variation between texts than in the textbook genre. In 4.3 and 4.4 I therefore provide a full analysis of two popular texts drawn from different genres (from Scientific American and the Mail and Guardian, cf. appendix pages 22 and 34) and aimed at different groups of readers. In my discussion of the Scientific American extract, I draw comparisons with the Time text (cf. appendix page 27), which has many similarities with it. In 4.5, I provide an analysis of an extract from a science book for children (cf. appendix page 45).

Originally four texts for children were analysed. Three proved to be very similar, and one, which shows some differences from the other three, I judged to be atypical and not representative of the genre. Nevertheless, as in 4.2, my account draws on the differences and similarities with the three texts that are not analysed in full. Finally, in 4.6, I summarise and report on my comparison of all the texts in the study.

Each of sections 4.1 to 4.6 may be regarded as a mini-chapter, each, as I note above being devoted to analysis of a different text. To assist readers, and to aid the process of comparison and generalisation, I follow the same organisational pattern in each of sections 4.1 to 4.6. In each I analyse register (context of situation) under the categories of field, mode and tenor in turn, and pay attention to the same features in each text. In each section I then move on to a consideration of genre (context of culture). Finally, in each of sections 4.1 to 4.6, I reflect on the second of my research questions, namely, the ideological assumptions of each genre in the study.

4.0.1 Note on convention used for numbering clauses

Clauses are numbered by use of a number in superscript at the beginning of each clause. Each clause complex is given its own number. Where there is more than one clause in a clause complex, this is indicated by letters of the alphabet. Thus the number before the following clause indicates that this is the second clause (b) in the fifth clause complex of the text:

^{5b}*or they may have become extinct over a very long time.*

Together with a photocopy of each text, the appendix contains copies of each text divided into numbered clauses. In this thesis I use italics to distinguish examples taken from the texts.

4.1 Raup and Sepkoski: An extract from a research article

4.1.0 Introduction

In this section I begin by examining an extract from a research article, it being the first of four different science genres that are central to my study. The other three are textbook accounts, the popular science article and books for children. The research article is 'Periodicity of extinctions in the geologic past', published in a prestigious journal, the Proceedings of the National Academy of Science. The findings of this article, and its authors, are mentioned in two of the popular articles (the Scientific American and Time texts) that I consider in 4.3. As a convenience I refer to the research article by the surnames of its authors, Raup and Sepkoski. As explained in 3.1.1, I have chosen sections from the representative parts of research articles: the Abstract, the Introduction, the Method, and the Discussion. This article also contains a speculative Implications section, and I include a paragraph from this section as well. The reader can consult the entire original text of the article by folding out page 3, 5 and 7 of the appendix. The analysed sections have been outlined in red ink.

I begin my account by considering the context of situation, or register, of the text, and I report on my analysis of register in terms of Field (in 4.1.1), Mode (in 4.1.2) and Tenor (in 4.1.3). I then go on, in section 4.1.5, to consider the context of culture, or genre of the text, before turning to ideology in 4.1.6. As mentioned in chapter 2 (section 2.3.2), Halliday (1993) indicates that we can expect the scientific register to be impersonal, highly nominalised with extended nominal groups, and to use a good deal of technical language and passive constructions. Moreover work by Bazerman (1988) and Myers (1989) leads us to expect the text to be persuasive in intent, in spite of lacking the usual interpersonal means of persuasion, i.e., attitudinal lexis and personal language.

4.1.1 Field in Raup and Sepkoski

Field is the first of three dimensions of register. It refers (cf. section 3.2.3) to what is being talked about, what is often referred to as experiential meaning. In this section I report on my investigation of human participants, processes, participants and circumstances in Raup and Sepkoski. Of these, human participants are particularly important in my comparison with other genres, necessitating consideration separately in each of sections 4.1 – 4.6.

4.1.1.1 Human participants in Raup and Sepkoski

Table 4.1.1 shows that there are very few human participants in the Raup and Sepkoski text. Passives are frequently used to avoid mention of human agency. Two of the human participants *Fischer and Arthur (4)* and *Shoemaker* are authors of other research articles. Mention of them constitutes what Hyland (1996) calls writer-oriented hedges, in which the authors back up their opinions by mentioning research that supports their opinions.

Table 4.1.1: Human Participants in Raup and Sepkoski

Clause 10a	Fischer and Arthur (4)	major clause, specific reference
Clause 27	we (the authors and probably includes the reader)	minor, specific
Clause 30b:	we (the authors)	major, specific
Clause 33a	Shoemaker	major, specific

As a whole the text is very impersonal. As is well documented, impersonality is an almost universal feature of research articles, and serves to create an impression of objectivity, which is so central to the establishment of the fact in scientific discourse. Personal language is avoided as it implies subjectivity and emotion, which, in the culture of science (and in western culture as a whole) is the opposite of objectivity and reason. Writers of research articles use personal language to serve very limited purposes. There are two uses of *we* in the analysed section of the text. In each case the writer uses the personal *we* presumably because the need to personalise exceeds the need to be impersonal: the instance of *we* in clause 27 is a form of solidarity politeness (Myers, 1989). Through using *we* the writers may hope to draw the reader into their speculation of "[27]*what we are seeing*". Here it seems that the need to involve the reader in their ideas exceeds the need to appear unemotional and objective. The use of *we* in 30a weakens the authors' case (Myers, 1989) by limiting the interpretation to themselves: "[30]*we favour*". This statement is made less threatening to the community by being limited to the authors. It seems that the authors suspect that the readers would not accept the claim of an extraterrestrial cause for periodic extinctions if too baldly expressed, because they have advanced no evidence at all for the claim. So the need to express this idea even in this weakened personal form must exceed the need to appear objective.

Interestingly, all but one human participant in the text appears in the <u>Implications</u> paragraph, where the writers are being most speculative. To minimise the possible offence to other researchers caused by their speculation that the cause of periodic extinction is extraterrestrial, in the face of the more widely accepted terrestrial explanation, the writers need to use these and other politeness strategies such as modalisation.

Table 4.1.2 shows just how striking Raup and Sepkoski's removal of themselves from the account is They sometimes construe themselves as 'this paper', but more often merely leave themselves (or others) out of the account (signified by [ ]).

Table 4.1.2 Human participants including those that the authors omit

Authors & others		
[ ]	used	time series analysis[1b]
Fischer &Arthur study	used	limited data[11a]
[Fischer & Arthur]	did	no statistical testing[11b]
this paper	uses	rigorous methods[12b]
[ ]	marked	the time series[15b]
[ ]	rescaled	the extinction data[16b]
[ ]	collected	values[17a]
[ ]	calculate	averages and ...[17b]
this paper	tests	periodicity[12a]
[ ]	investigate	temporal distribution of extinction[1a]
[ ]	based	the analysed record on ...[2a]
[ ]	assume	extinction is continuous[7a]
Fischer & Arthur	argued	periodicity in extinction events [10c]
We	favour	extraterrestrial causes[30b]

Some of the human participants in Raup and Sepkoski constitute intertextual references (clauses 8, 10a, 10d, 24b, 33a, 33c), all to research articles, making it clear that other research articles (rather than popular sources or interviews) are authoritative sources in this text. This is, of course, the norm in academic discourse where publication of claims is the first step towards acceptance of one's ideas by the scientific community (Myers 1989).

In summary, there are very few human participants in Raup and Sepkoski, making for a very impersonal text, which in turn assists the impression of objectivity of the text. I argue below that two of the human participants serve to back up the writers' opinions. The other two human participants serve purposes of politeness – in the one case attempting to include the reader in the writers' beliefs and in the other showing deference to the discourse community by conceding that an opinion that goes against currently accepted knowledge is limited to the authors. All four human participants are specific references (who they are is important). This is a highly impersonal text, with all but two of the five mental and four verbal processes lacking a senser/sayer. As discussed in chapter 2 (section 2.3.2), ideas achieve objectivity and thus factual status in science by the removal of the fact from people, including the people who originated the idea.

4.1.1.2 Processes and participants in Raup and Sepkoski

Here I consider the kinds of processes that are common in the different parts of this text, i.e., in the Abstract, the Introduction, the Results section, the Method section, the Discussion and the Implications section. I begin my account as a whole by summarising the number and types of processes in each section of the text in Table 4.1.3. I then consider each section in turn in greater detail. Tables 4.1.4 to 4.1.9 reflect the participants, processes and circumstances in each section of the text. Accompanying each table is a discussion of how meaning is construed in the section.

Table 4.1.3: Summary of kinds of processes in different sections of Raup and Sepkoski

	material	mental	verbal	identifying	attributive	behavioural	existential	total
Abstract	2			2	2	1		7
Introduction	7	2	2	2	2		1	16
Results				2				2
Method	4			1	1	2		8
Discussion		2		9	4			15
Implications	3	1	2	6	7	3		22
total	16	5	4	22	16	6	1	70

Although the Introduction to Raup and Sepkoski deals with ideas (often construed elsewhere as relational processes), Table 4.1.3 shows that there are a high proportion of material processes in the Introduction. Most of these describe what Fischer and Arthur and the authors do. The Method section also has a high proportion of material processes, but this is expected, as the section describes what was done in the research. A further interesting feature is that more than half the processes in the text are relational. Significantly, most of these appear in the Discussion and Implication sections where the authors analyse and interpret their results, and need to show relations of equivalence or cause.

Table 4.1.4 shows the processes and participants in the abstract of Raup and Sepkoski. As expected, the abstract is a condensed version of the article. The participants are:
[1a, 3, 4]*extinction events*, [5a]*causes of periodicity*, in particular, [5b]*extraterrestrial forces and* [2a]*the fossil record*. In brief in the Abstract the authors note that these participants [1a]*have been investigated* (agent omitted) statistically. The knowledge claim made is a [3]*statistically significant periodicity of extinction events*. There is one passive behavioural process (*has been investigated*), which, however, cannot be said to serve to obscure the participants as these are easily recovered from context. Rather this passive process focuses attention on the content. The identifying processes show equivalence ([4]*coincide with*) and cause ([3]*show*), while the attributive processes evaluate [5a]*the causes of periodicity* as [5a]*unknown* and [5b]*possible*.

Table 4.1.4: Processes and non-human participants in Raup and Sepkoski: Abstract

	Actor	Material	Goal/range	Circumstance
1b		using	various forms of time series analysis (range)	
2a		is based	The analysed record Range: on variation in extinction intensity	
	Token	**Ident: circum**	**Value**	
4	Two of the events	coincide	with extinctions that have previously been linked to...	
3	The 12 events	show	a statistically significant periodicity ...	with a mean interval of...
	Carrier	**Attributive**	**Attribute**	
5a	the causes of ...	are	unknown	
5b	it	is	possible	
	Behaver	**Behavioural**	**Matter**	
1a		has been investigated	The temporal distribution of the major extinctions ...	statistically

The first sentence of the abstract is different from the rest of the paragraph in being in the past tense rather than the present. This reflects the fact that this sentence is reporting on what actually happened in the authors' research, while the rest of the paragraph uses the present tense - the tense used for general truths (Leech and Svartik 1975) or facts, removed from time. Raup and Sepkoski is thus indicating that its findings add to this generally true factual information.

In general terms the Introduction (see Table 4.1.5) serves to set up an opposition between the conventional explanation for extinction events (a [7a]*continuous process* which is [8]*time homogenous*) and that favoured by the authors ([10c]*periodic mass extinction*). Those holding the gradualist view are not explicitly named. In the mental and verbal processes that refer to them, there are no obvious people doing the saying or thinking. These unspecified people who [8]*have often described* or [7a]*have generally assumed* are a large

Table 4.1.5: Processes and non-human participants in Raup and Sepkoski: Introduction

	Actor	**Material**	**Goal/range**	**Circumstance**
8b		using	standard birth-death models	
10a	Fischer and Arthur	departed from	convention	
10c	major extinction events of the past 250 million years (ma)	occurred		periodically at ... constant intervals of ...
11a	Their study	used	a limited data base,	
11b		was done	no statistical testing	
12a	The purpose of ...	is to test	the proposition of periodicity ...	
12b		using	as rigorous a methodology	
	Senser	**Mental**	**Phenomenon**	
7a		has been ... assumed	It...FACT (that extinction is a continuous process)	
10d		see	ref. 5	
	Sayer	**Verbal**	**Verbiage/Range**	
8a		is often described	the extinction process /as a time homogeneous process	
10b		arguing	FACT that major extinction events occurred periodically...	
	Token	**Ident: Intens**	**Value**	
6b	the ... fossil record	documents	some 200,000 such extinctions.	
7c	mass extinctions	reflect	... short-term increases in that risk.	
	Carrier	**Attributive**	**Attribute**	
6a	Virtually all species...	are	Extinct	now
7b	species	are	at risk	
		existential	**existent**	
9a	There	is	increasing evidence [[FACT that many extinctions are ...]]	

group of other researchers with whom the authors, in this instance, disagree. To achieve this omission of human agency, these processes are passive. Most material processes on the other hand are active and their agents are Fischer and Arthur (whose work the authors support), their study, and also the authors' purpose and their data. This projects a world in which data and research rather than people are prominent.

The authors use the Introduction (as Swales (1984) notes) to indicate a gap for their research: they note that Fischer and Arthur (whose work they agree with and extend) relied on [11a]*a limited data base* and [11b]*no statistical testing was done*. This is their niche or field (in Swales' (1984) terms) and they undertake to use [12]*as rigorous a methodology as present data permit*.

Table 4.1.6: Processes and non-human participants in Raup and Sepkoski: Results

	Token	Ident: circumstatial	Value
13	in Fig 4	are illustrated	The results of a final test of the extinction record
	Token	**Ident: Intens**	**Value**
14	This figure	represents	a "composite cycle"

The two clauses that can be said to play the role of a Results section (see Table 4.1.6) serve merely to direct the readers to the relevant figure, which shows the data, and indicate a relationship of equivalence between *figure 4* and what it represents.

Table 4.1.7: Processes and non-human participants in Raup and Sepkoski: Method

	Actor	Material	Goal/range	Circumstance
15b		was marked off	the time series	at 26 ma intervals
16a		were rescaled	The extinction data in each interval	
17a		were collected	these values	with their counterparts ...
18		was performed	this procedure / for a variety of interval lengths	
		Behavioral	**Matter**	
15a		To compute	the composite	
17b		were calculated	averages and dispersions	
	Token	**Ident: Intens**	**Value**	
15c	the C-T boundary peak	was	at the center of one interval.	
16b	100%.	was	the maximal value	

As has often been pointed out, the Method in science research articles is recounted almost entirely through the use of passive processes. In the Method section in Raup and Sepkoski (see Table 4.1.7), there are no agents *marking off*, *rescaling*, *collecting*, or *performing*; similarly there are no people doing the *computing* and *calculating*. However this omission does not obscure that who performed these actions is one or both of the authors. The passives instead foreground the data and the methods in an efficient, impersonal and economical way. This in turn projects a view of research as efficient and impersonal.

Table 4.1.8: Processes and non-human participants in Raup and Sepkoski: Discussion

	Senser	**Mental**	**Phenomenon**	**Circumstance**
22a		should be noted	It. FACT (that the composite curve rises to a sharp peak)	
23a		would be expected	a composite curve ...	
	Token	**Ident: Intens**	**Value**	
19a	The illustrated composite cycle	represents	a best-fit to the data	
20a	Tests of the medians	show	highly significant differences:	
21a	Other cycle lengths	*give*	less significant results	
22c		does not prove		
24a	The curve in Fig 4	may represent	a rather conservative illustration of ...	
	Token	**Ident: circum**	**Value**	
20b	A Friedmann's test ...	results	in an S value of 250 ...	
21c	the cycle	departs	from the best-fit cycle	substantially
24b	much of its breadth	may result	from the interval nature of the data ...	
	Carrier	**Attributive**	**Attribute**	
19b	the composite peak	has	maximal amplitude and minimal dispersion	about the median ...
21b	the composite curve	deteriorates into	an irregular, non-unimodal curve (noise)	
22b	which	is	compatable with the proposition that ...	
25	The slight asymmetry of the curve in Fig 4	is	consistent with this last proposition.	

In general the Discussion (see Table 4.1.8) in Raup and Sepkoski is about how the statistically manipulated data are represented in the curve, and what picture the curve presents of the nature of extinction events. Real past creatures and events, as evidenced in fossils, are represented in a highly abstract way, in the composite curve, and subjected to statistical testing. As in most sections of this article, there are no human participants. *The curve in figure 4* is under discussion, and most participants refer to it. Another prominent set of participants is the statistical methods and their use in the data. The world represented in the Discussion is an abstract world, in which mathematical/statistical methods allow us to reflect remote events graphically and then to interpret this graph to tell us something about the remote events.

Most processes are relational, and many of these are cause and effect/reasoning processes. There is a high degree of nominalisation of the participants in the text (cf. 4.1.2.2). This nominalisation together with the reasoning verbs allow the authors to cite much of their reasoning within clauses, rather than using conjunctions to effect reasoning (cf. 4.1.2.4).

Table 4.1.9: Processes and non-human participants in Raup and Sepkoski: Implications

	Actor	**Material**	**Goal/range**	**Circ**
30e		measured	on a timescale of millions of years	
33b		should increase	the comet flux	
		is needed	much more information	
	Senser	**Mental**	**Phenomenon**	
30b	we	favour	extraterrestrial causes	
	Sayer	**Verbal**	**Verbiage/Range**	
33a	Shoemaker	has argued	that passage through galactic arms should ... FACT	
35b		can be made	**definitive statements about causes**	
	Token	**Ident: Intens**	**Value**	
27	A first question	is	whether ...FACT	
28b	this	does reflect	an earthbound process or ...	
32a	the passage of our solar system through	is	one possibility	
33c	this	could provide	an explanation for the biological extinctions.	
34	Two of the ... events	are associated	with evidence for meteorite impact	
36	It	may turn out	that (FACT)	
	Carrier	**Attributive**	**Attribute**	
26b	the implications	are	broad and fundamental	
28a	the forcing agent	is	in the physical environment,	
29b	the extraterrestrial influences	are	solar, solar system, or galactic?	
30c	purely biological ... physical cycles	seem	incredible	
30d	the cycles	are	of fixed length	
31a	astronomical and ... cycles of this order	are	plausible	
31b	few	are	candidates	
		Behavioral	**Matter**	
26a		can be demonstrated	periodicity of extinctions in the geologic past	
30a		can be ruled out	none of these alternatives	now
32b		has been estimated to occur	on the order of 10^8 years	

Mental processes in the Discussion have no senser but can be inferred to refer to the reader who [22a]*should note* and who (along with the authors) [23a]*would expect*... In a highly impersonal text this is as close as the writers get to referring directly to the reader.

The overriding purpose of the Implications section (see Table 4.1.9) is speculation. It therefore contrasts with the rest of the article in a number of ways, which I now describe. Firstly, the Implications section does have human participants. These are *Shoemaker*, who is another researcher, and the authors, "*we*" (twice). As discussed above, the use of [30b]*we* in [30b]*We favour extraterrestrial causes* is, a politeness strategy showing deference to readers (Myers 1989). More deference to readers is in the authors' use of the mental process [30b]*favour*, which indicates that this interpretation is a choice: others are possible. The other use of *we* in clause 27 also shows deference in that it invites the readers to participate in the process of speculating on what [27]*we are seeing* in the data.

A number of processes in the Implications section are modals. This also reflects the fact that this paragraph is very speculative and thus needs to be tentative. The authors have no evidence to support their suggestions, and can only claim that they are '*plausible*', and that counter-possibilities '*seem incredible*'.

Overall, Table 4.1.10 below shows that meaning in Raup and Sepkoski is largely construed though identifying processes (meanings to do with the two theories of extinction and meanings to do with Fig 4). Material processes are largely used in connection with the authors' methods. The lexis, while abstract and technical (e.g. *time series analysis*) is more simple and less abstract than that found in for example Duff (see section 4.2). Like Duff, Raup and Sepkoski is about theories of extinction, not about dinosaurs; and like McGhee (see 4.2) it is about evidence for how extinction might have happened. Unlike McGhee, however, only one particular kind of evidence is mentioned, and this in great detail. This, of course, is the difference between a textbook, which seeks to give an overview (varying in depth depending on the projected readers), and a research article, which is focused on a particular limited field of research.

Table 4.1.10: Construal of meaning in Raup and Sepkoski

		Methods & data						
Fig 4	shows	results						
Fig 4	is	a composite cycle						
		Composite cycle	is	best-fit to data				
	identifying		identifying					
		Tests	show	significant differences				
		Other cycle lengths	give	less significant results				
Fig 4	is	composite curve	rises to	sharp peak				
Fig 4	is			illustration of extinction				
[ ]	used	time series analysis						
F&A study	used	limited data		Statistical methods prove periodicity				
[F&A]	did	no statistical testing						
	material							
this paper	uses	rigorous methods						
[ ]	marked	the time series						
[ ]	rescaled	the extinction data						
[ ]	collected	values		Theory: Extinction slow			Theory: Extinction	
[ ]	calculate	averages and ...		and gradual			short-lived and	
				extinction		periodicity	periodic	
						periodicity		
this paper	tests							
[ ]			investigate	distribution of extinction				
[ ]	analysed			extinction of vertebrates				
[ ]	assume			extinction	is	continuous		
				mass extinctions	reflect	increases in risk		
				extinction	described	as homogeneous		
	mental				ident			Causes of periodicity
		The analysed record	contains	12 Extinction events	show	periodicity	caused by	unknown
Fischer & Arthur	argued	Fossil record	documents	2 events			caused by	ET forces
				200000 extinction			linked to	meteorites
				extinctions	are	short-lived		
				extinctions	are	periodic		
					ident		identify	
				Extinctions	are	discrete events		
						cause of periodicity	is?	biological
We	favour						is?	physical?
						cause of periodicity	is?	Earthbound
Authors						periodicity	caused by	ET causes
& others						possible causes	are	solar syst
								galactic
								comets

Circumstances in Raup and Sepkoski

The circumstances in all the texts in this study are most commonly of duration, location of time and place and manner, and these are indeed the circumstances found in this text. Because of the variation in the different sections of a research article, it is not possible to draw any conclusions about circumstances in different sections of this article (reflected in Table 4.1.11) beyond the fact that few circumstances are found.

Table 4.1.11 Circumstances in Raup and Sepkoski

	abstract	introduction	results	method	discussion	implications	total
Extent: duration		2					2
Location: place				1	1		2
Location: time		1				1	2
Manner	2				1		3
Accompaniment				1			1
							10

4.1.1.3 Summary and overview of field in Raup and Sepkoski

This examination of Field indicates that Raup and Sepkoski is a highly impersonal text with only four human participants – two citations that back up the writers' theories, and two that show politeness to the reader (who represents the research community). Myers (1989) has indicated that such politeness is a feature of research articles, and a sign of the persuasive function of research articles. Another contributor to the impersonality of the text is that the mental and verbal processes are mainly agentless passives.

The above analysis of participants and processes shows that identifying processes are the most common processes in the text as a whole, indicating a text that is concerned to show equivalence relations and, more prominently, causal relations. Causal relations are achieved incongruently through causal processes rather than congruently through conjunctions, a sign of a more 'written' text. Material processes are particularly prominent in the <u>introduction</u> (explaining what other researchers have done) and the <u>method</u> section (explaining what the authors have done). The text reports what was done (realised in material processes), what was proved statistically (identifying processes) and what this implies (identifying and attributive processes). Overall Raup and Sepkoski uses identifying clauses to translate what the researchers did in their research (material processes) into abstract statistical meanings. They then draw conclusions about what this implies, which is also abstract (using identifying and attributive processes). This text contains mathematical abstraction (statistical meaning), making it harder for readers than are other texts in the study, as we see later in this chapter. Raup and Sepkoski focuses on a very limited field – their research - compared to a far wider range in each of the other texts in my study.

4.1.2 Mode in Raup and Sepkoski

In this section, under the categories of theme, nominalisation and embedding, passivisation and conjunctive relations, I reflect on how Raup and Sepkoski organises its message.

4.1.2.1 Theme in Raup and Sepkoski

I argue below that the writers employ marked themes to track the progression of their argument. By using β clauses (dependant clauses, see 3.2.4.1) that act as theme, interpersonal themes and textual themes, they signal what is important and what the reader should pay attention to. Marked themes are particularly prominent in the Implications

Table 4.1.12: Theme in Raup and Sepkoski

	Textual	Interpers.	Topical	Rheme *
Abstract				
1a			The *temporal distribution* of the *major extinctions* over the past 250 million years	'heavy' theme
2a			The *analysed record*	
2b	and		*	
3			*The 12 events*	
4			*Two of the events*	
5a			**Although the *causes* of *periodicity* are unknown**	β clause as theme
Introduction				
6a			Virtually all species of animals and plants [[that have ever lived]]	'heavy' theme
6b	and		the *known fossil record*	
7a		**It has**	**generally been assumed**	Interpers.
7b	in the sense that		species	
7c	and that		mass extinctions	
8a	**Following this view**		the *extinction process*	conditional
9			There	
10a			Fischer and Arthur	
		by arguing		Interpers.
			major extinction events [of the past 250 million years (ma)]	'heavy' theme
11a			*Their study*	
11b			*no statistical testing*	
12a	therefore		The purpose of this paper	causal

'Best fit' cycle: includes Results, Method, Discussion			
Results			
13		The *results* of a *final test* of the *extinction record*	
14		This figure	
Method			
15a		**To compute *the composite***	β clause
16a		The *extinction data*[[in each interval (interpolated to every 1 ma)]]	'heavy' theme
16b	so that	the *maximal value*	
17a		*These values*	
17b	and	*averages* and *dispersions*	
18		*This procedure*	
Discussion			
19a		The *illustrated composite cycle*	
19b	in the sense that	the *composite peak*	
20a		*Tests* of the *medians*	
20b		a *Friedmann's test* [[for points separated by 6 ma (the approximate average stage duration)]]	'heavy' theme
21a		Other cycle lengths	
21b	and	the *composite curve*	
21c	when	*the cycle*	
22a	It should	be noted	interpers
23a		**If *extinctions* resulted from continuous *fluctuations* in background rate**	β clause as theme
24a		The *curve* in Fig 4	
24b		much of its breadth	
25		The slight *asymmetry of the curve in Fig 4*	
Implications			
26a		**If *periodicity of extinctions* in the *geologic past* can be demonstrated**	β clause as theme
27		A first *question*	
28a		**If the forcing agent is in the physical environment**	β clause
29a		**If the latter**	β clause
30a		**Although none of these alternatives can be ruled out now**	β clause as theme
31a	By contrast	Astronomical and astrophysical cycles of this order	contrast
31b	even though	candidates [[for the particular cycle observed in the extinction data]]	'heavy' theme Conditional
32a		One *possibility*	
32b		which	
33a		Shoemaker	
33b		passage through galactic arms	
33c	and	this	
34		Two of the *extinction events*	
35a	However	much more *information*	adversative
35b	before	*definitive statements* about *causes*	
36a	**It may**	**turn out**	Interpers.

1. **clause as theme: bold**; marked theme: underlined; *nominalisations: italicised*
2. * In this column I signal the markedness of themes using Gosden's (1992) categories.
3. The double border signals the breaks between the three extracts form the article

section, where the writers have least justification for what they say and are thus most at pains to persuade the reader and therefore most need to direct the attention of the reader. Of interest is the complete lack of adjuncts in marked thematic position in the text: it is not time, place or manner that the writers take as their starting point.

Theme, as I pointed out in 3.2.4.1, is often described as the 'point of departure' for the clause. For Gerot (1995:78) theme is significant for two reasons: because it carries the topic of the clause and also because it generally (but not always) reiterates *given* information which was *new* in a previous clause, thus constituting the thread of what is being said and linking clauses together. Looked at from this point of view, the first theme of the Abstract, [1a]*The temporal distribution of the major extinctions over the past 250 million years*, can be said to be the topic for the whole article. This is a 'heavy' theme, which Thompson (1996:141) says may be used to specify the framework for interpretation. The thread continues through the [2a]*analysed* (fossil) record, which is the medium in which the extinctions are reflected, to [3]the 12 (extinction) events, to the [5a]*causes of the periodicity*, of these extinctions. The abstract ends with a β clause as theme, signalling, perhaps, the fact that this clause contains speculative information. The abstract shows maintenance of theme (choice of same theme as previous clause) and progression of theme (choice of theme from an element of the previous rheme) (Thompson 1996:141).

The Introduction, like the abstract, starts with a 'heavy' theme. It shows some maintenance of theme (choice of same theme as previous clause), and also uses textual and interpersonal themes to track the course of the writers' argument. This argument is that there have been [7a]*certain assumptions* with [8a]*certain implications*, but that there is evidence (to which the writers add) that these assumptions are wrong: [7a]*It has generally been assumed*; [8a]*Following this view*; [10]*by arguing*, [12a]*The purpose of this paper, therefore*.

It is particularly noticeable of the themes in the Method section (clause 13-18) that almost all of them are the subject of passive constructions. As discussed in connection with Table 4.1.7, the people doing the method are omitted, and the focus is on what was done and to what, and not on by whom it was done. In the context of the Method section of a research article, passive constructions are actually not marked forms at all. Rather, they are expected. The unmarked nature of the patterning in clauses 13-16 is also reflected in the 'zig-zag' pattern (Danes 1974). Theme is an element of the previous rheme indicating progression of what the text is about (Thompson 1996:141):

<u>theme</u>		<u>rheme</u>
The results of a final test...	→	are illustrated in Fig 4
This figure	→	represents a "composite cycle"
To compute the composite	→	the time series was marked off at 26-ma intervals
The extinction data in each interval		

Looking at the 'best-fit' cycle as a whole, we find that the themes in this section of the text focus on figure 4. The curve in this figure, how it was arrived at and what statistical tests it was subjected to are the subject of the 'best-fit' cycle. The marked topical theme, [15a]*To compute the composite*, is the first theme of the <u>Method</u> move in the extract. By using a marked theme in this way the writers foreground the start of the <u>Method</u> move. A second marked theme, [22a]*It should be noted that*, is foregrounded in other ways - it is one of only two mental processes in the 'best fit' cycle, it is imperative, and it is passive. It serves to draw the readers attention to and stress the important message of the extract and of the article as a whole, [22b]*the proposition that mass extinctions are discrete events*.

The <u>Discussion</u> section uses both maintenance and progression of theme. Two marked themes (the first an interpersonal theme and the second a β clause as theme) stress what is particularly important in this part of the research: that the curve rises to a sharp point, which is not consistent with the idea that extinction happens at a steady rate: [22a]*It should be noted:* [23a]*If* ***extinctions*** *resulted from ...* ***fluctuations*** *in background rate*.

In the <u>Implications</u> section, the authors use a number of β clauses which act as theme to trace the thread of their argument: [26a]*If periodicity of extinctions in the geologic past can be demonstrated ...;* [28a]*If the forcing agent is in the physical environment ...;* [29a]*If the latter ...;* [30a]*Although none of these alternatives can be ruled out now ...*

In the <u>Implications</u> section, by using β clauses that act as theme, the authors are able to argue for a suggestion for which they actually have very little evidence. However their careful use of modality and hedging in this paragraph mean that the authors cannot be accused of pretending that their speculation is fact (in the sense of being accepted by the research community). The themes in the Implications section, in particular the large number of marked themes actually serve to foreground the tentative nature of what is being said. Almost all of these marked themes contain an element stressing tentativeness and conditionality:

- Three clauses start with *if* (26a, 28a, 29a)
- There are three modal verbs
- One clause mentions a [27]*question*, another mentions [32a]*possibility*.

Throughout the analysed text, the instances where a clause is theme (bold in table 4.1.12) usually trace the thread of the authors' argument. These are instances where the authors are explicitly directing the argument, stepping back from the content to an extent and providing signals about where the argument is going. Use of a clause as theme in this way is particularly prominent in the Implications section:

[5a]*Although the causes of periodicity are unknown;* [7a]*It has generally been assumed ...;* [8]*Following this view ...;* [9]*There is increasing evidence however ...;* [15a]*To compute the composite ...;* [22a]*It should be noted ...;* [23a]*If extinctions resulted from continuous fluctuations in background rate ...;* [26a]*If periodicity of extinctions in the geologic past can be demonstrated ...;* [27]*A first question is ...;* [28a]*If the forcing agent is in the physical environment ...;* [29a]*If the latter ...;* [30a]*Although none of these alternatives can be ruled out now ...;* [36]*It may turn out ...*

In summary, marked themes (usually β clauses which act as theme with some interpersonal and textual themes) are used to mark the progression of the writers' argument concerning periodicity of extinction and the possibility of the cause of extinction being extraterrestrial. These marked themes, signs of the authors' particular wish to direct the argument and control the attention of the readers, are particularly marked in the Implications section where the authors have least evidence for what they say.

4.1.2.2 Nominalisation and embedding in Raup and Sepkoski

Nominalisation, as first noted in 2.4.2, turns a process into a thing and locates it in the nominal group. Embedding extends the nominal group, but locates a phrase or clause within it.

Nominalisation in Raup and Sepkoski

There is much nominalisation in Raup and Sepkoski: 39 different nominalisations in a 900-word text. These are:

[1a]*distribution*, [1a]*extinction*, [1b]*analysis*, [2a]*variation*, [2a]*intensity*, [5a]*causes* [5b]*forces*, [6b]*record*, [7a]*process*, [7c]*increases*, [9]*evidence*, [11a]*study* [11b]*testing*, [12a]*periodicity* [12b]*proposition*, [15a]*composite*, [17b]*dispersions*, [18]*procedure*, [18]*variety*, [18]*lengths*, [19a]*best-fit*, [19b]*dispersion* [20a]*medians*, [20a]*differences*, [20b]*duration*, [21b]*curve*, [23a]*fluctuations*, [24a]*illustration*, [24a]*abruptness*, [24b]*breadth*, [24b]*error*, [24b]*failure*, [25]*asymmetry*, [26b]*implications*, [29b]*influences*, [32a]*possibility*, [33c]*hypothesis*, [35a]*information*, [36]*indicators*

This large amount of nominalisation in Raup and Sepkoski corresponds to a marked degree to Halliday's (1993:90) characterisation of science texts as construing processes (such as distribute and record) and attributes (such as extinct and intense) as nouns ([1a]*distribution*, [6b]*record*, [1a]*extinction*, [2a]*intensity*.) Correspondingly logical relations (typically realised as conjunctions and prepositions) are realised as verbs ([23a] *resulted from*, [2a]*is based on*, [7c]*reflect*).

This extensive nominalisation results in a high level of abstraction, as if events are held at arms' length and have little to do with the writers or with people in general. As discussed above (4.1.2.1), the function of this nominalisation is facilitating cause and effect argument. Although the primary function may be one of efficiency in argument, one effect, nevertheless, is the removal of people from the account. In some places there also seems to be use of nominalisation deliberately to conceal agency:

[12a]*The purpose of this paper, therefore, is to test the* ***proposition*** *of periodicity in the record of marine extinctions over the past 250 ma.* [Whose proposition? This avoids the fact that it is the authors' proposition]

[11a]*Their study used a limited data base,* [11b]*and no statistical* ***testing*** *was done.*

[Rather than "and they did not test this statistically". The authors wish to criticise Fischer and Arthur's method but for reasons of politeness do not reiterate their names in connection with the criticism, using nominalisation to avoid this]

Many of the nominalisations in the text are technical terms, which the writers assume the readers are already familiar with, making the text difficult to understand for those unfamiliar with the field. Examples are: [1a]*distribution*, [1b]*analysis*, [2a]*variation*, [6b]*record*, [19a]*best-fit*, [19b]*dispersion* [20a]*medians*, [21b]*curve*.

In summary, there is a high level of nominalisation in this text, much of it functioning in efficiency of cause and effect argument and much of it functioning as technical terms. This results in a high level of abstraction and a removal of people from the account.

Embedding in Raup and Sepkoski

In general terms the embedding in this extract seems to be of two types. Firstly, there are fact clauses into which significant propositions are packaged. Secondly there are other embedded clauses which serve largely to provide information on a greater level of specificity than the ranking clause but which could often be omitted without negatively affecting the meaning.

Embedded fact clauses

The author usually uses the ranking part of the sentence to comment on the status (credibility) of the fact (see underlined parts below):

In the <u>Abstract</u> the speculation developed later in the <u>Implications</u> section is packaged into a fact clause: [5b]*<u>it is possible</u> [[that they are related to extraterrestrial forces (solar, solar system, or galactic).]]*

In the <u>introduction</u> the fact clauses serve to encapsulate the two possible arguments:

[7a]*<u>It has been generally assumed</u> [[that extinction is a continuous process]]* [7b]*in the sense that species are always at risk* [7c]*and that mass extinctions simply reflect relatively short-term increases in that risk.*
[9]*<u>There is increasing evidence</u>, however, [[that many extinctions are actually short-lived events of special stress, separated by periods of much lower, or even negligible, risk.]]*
[10a]*<u>Fischer and Arthur (4) departed from convention</u>* [10b]*<u>by arguing</u> that* [10c]*[[major extinction events of the past 250 million years (ma) occurred periodically at nearly constant intervals of 32 ma]]*
[12a]*The purpose of this paper, therefore, is to test <u>the proposition</u> [of periodicity in the record of marine extinctions over the past 250 ma (Late Permian to recent)]*

In the <u>Discussion</u> section a fact clause is used to encapsulate a highly significant aspect of the graph which the authors wish to draw attention to:

[22a]*It should be noted [[that the composite curve in Fig 4 rises to a fairly sharp peak,]]* [22b]*which is compatible with ([22c]although does not prove) the proposition [[that mass extinctions are discrete events.]]*

In the Implications section the writers package in a fact clause a finding which supports their speculation of an extraterrestrial cause for mass extinction: [33a]*Shoemaker has argued (21) [[that* [33b]*passage through galactic arms should increase the comet flux.]]*

They also package as a fact their almost formulaic statement that future research may uncover new evidence: [36]*It may turn out [[that the biological record is sensitive to periodic phenomena that other indicators have failed to recognise.]]*

Besides this final example, significant propositions such as hypotheses are packaged as facts. Gerot (1995:96) maintains packaging something as a fact enhances its 'givenness' and 'acceptedness'. However it is often the case that fact clauses are packaged as such because someone is quoted as saying them. This may not eliminate the suspicion that the author wishes to convey 'given' or 'accepted' status on them. Indeed attributing ideas to others is a way (prominent in the popular texts) of claiming objectivity for the writer, thus increasing the status of the proposition.

Embedded clauses providing information of greater specificity than the ranking clause

A second group of embedded clauses serve to provide information on a greater level of specificity than the ranking clause but could often be omitted without negatively affecting the meaning. This function of embedded clauses is found in clauses 6a, 10c, 12b, 13, 14, 16a, 20b, 23b, 24a, 31a, 33c and 34. Examples are:

[6a]*Virtually all species of animals and plants [[that have ever lived]] are now extinct.*
[16a]*The extinction data [in each interval (interpolated to every 1ma)] were then rescaled.*

The embedded clauses and phrases in clause 1a, 4, and 32a are central to meaning in the ranking clause and strike me as adjective-like extensions to the nominal group. For example:

[1a]*The temporal distribution [of the major extinctions over the past 250 million years] has been investigated statistically...*

In summary, embedded fact clauses in this text allow the writers to package central propositions into facts whose credibility the ranking clause can either bolster or reflect negatively on Much of the other embedding in the text adds to the nominal group information of a greater level of specificity than that found in the ranking clause.

4.1.2.3 Passivisation in Raup and Sepkoski

The reason for using the passive in this text is more complex than in any of the other texts, mainly because in a research article it is necessary to show deference to the research community (cf. Myers 1989). There are 19 passive processes in this 916-word extract. The omitted agent is overwhelmingly either the authors or other researchers. Omission of the agent serves three main purposes in Raup and Sepkoski. Firstly passives can serve the textual purpose of thematising Given information and foregrounding the findings and methods of the researchers rather than the researchers themselves (this could also be seen as a kind of politeness where the writers are self-effacing). Secondly they serve the purpose of politeness (e.g. omitting the names of other researchers when the authors wish to criticise the ideas of these researchers). Finally they can bolster the authors' case by including the reader in suppositions or giving opinions an appearance of being very widely accepted. I consider each of these three functions in turn. Verbs in the passive voice in the examples below are in bold face:

1) **The textual purpose of thematising Given information or of foregrounding the findings and methods of the researchers rather than the researchers themselves.**

[1a]*The temporal distribution of the major extinctions ... **has been investigated** [by us]* [1b]*using various forms of time series analysis* [2a]*The analysed record **is based** on variation* [by the authors]

[13]*The results of a final test of the extinction record **are illustrated** in Fig. 4.* [14]*This figure represents a "composite cycle" ...* [15a]*To compute the composite,* [15b]*the time series **was marked** off at 26-ma intervals* [15c]*in such a way that the Cretaceous-Tertiary boundary peak (at 65 ma B.P.) was at the center of one interval.* [16a]*The extinction data in each interval (interpolated to every 1ma) **were then rescaled*** [16b]*so that the maximal value was100%.* [17a]*These values **were collected** with their counterparts in other intervals* [17b]*and averages and dispersions **were calculated**.* [18]*This procedure **was performed** for a variety of interval lengths* [by the authors]

2) The purpose of politeness

- Omitting the names of other researchers when the authors wish to criticise the ideas of these researchers:

[7a]***It has been generally assumed** that extinction is a continuous process..* [8]*Following this view, the extinction process **is often described** as ...*[9]*There is increasing evidence, however, that many extinctions are actually short-lived events* [by other researchers]
[11a]*Their study used a limited data base,* [11b]*and no statistical testing **was done**.*
[by Fischer and Arthur]

- Giving the readers an order but making it polite by omitting reader as agent:

[22a]***It should be noted** that the composite curve in Fig 4 rises*

- Formulaic admission by the authors that they have not fully proved their case:

[35a]*However much more information **is needed*** [35b]*before definitive statements about causes **can be made**.* [by the authors or any other researchers]

3) Use of the passive to bolster the authors' case (by making it appear widely acccepted):

[4]*Two of the events coincide with extinctions that **have previously been linked** to meteorite impacts* [by other unnamed researchers]

[23a]*If extinctions resulted from continuous fluctuations in background rate,* [23b]*a composite curve approaching a sine-cosine function **would be expected**.*
[by the authors, readers, and all mathematically literate people]

[26a]*If periodicity of extinctions in the geologic past **can be demonstrated**,* [26b]*the implications are broad and fundamental.* [by the authors or other researchers: omission of agent/passive with modal (if...can) allows authors to proceed with their speculations in the expectation that it <u>will</u> be demonstrated]

[30a]*Although none of these alternatives **can be ruled out** now* [by the authors or any one else: omission of agent/passive with modal allows authors to continue speculating along their chosen line]

[32a]*One possibility is the passage of our solar system through the spiral arm of the Milky Way Galaxy,* [32b]*which **has been estimated** to occur on the order of 10^8 years* (21).
[by Shoemaker – footnote 21]

[34]*Two extinction events (Late Cretaceous and Late Eocene) **are associated** with evidence for meteorite impact* (23, 24). [By other named researchers – footnotes 23 and 24]

In short, the wide use of passivisation/removal of the agent serves a more complex purpose than in any of the other texts, largely due to the need to persuade the readers to accept what is advanced by the authors. The three main purposes served are: the textual function of thematising Given material or foregrounding something other than the agent which is important; showing politeness to readers to persuade them to accept what is advanced by the authors; omission of a specific agent to indicate wide/general acceptance of the ideas advanced. Only the first of these three functions is common in the other texts in the study.

4.1.2.4 Conjunctive relations in Raup and Sepkoski

External conjunctions express relations between events in the real world (Gerot 1995:100), while internal relations are rhetorical relations within the text itself (Martin 1993: 233). Raup and Sepkoski is unusual in the texts analysed in this study in that it has many internal conjunctive relations (concerned with rhetorical structure). Below I argue that these function in persuading the reader to accept the writers' explanation.

Table 4.1.13 Conjunctive Relations in Raup and Sepkoski

Internal conjunctive relations: rhetorical structure	clause	External: real world conjunctive relations	
Paragraphs 1&2 (abstract &	1a		
introduction)	1b		
	2a		
	2b	Extension: addition	and
	3		
	4		
	5a	Conditional: concessive	Although
	5b		
	6a		
	6b	Extension: addition	and
	7a		
Elaboration: expository	7b		in the sense that
conditional	8		Following this view
	9	Extension: adversative	However
	10a		
	10c		
	10d		
	11a		
	11b	Extension: addition	and
Causal-conditional: general	12a		therefore
	12b		
Paragraph 27&28:	13		
	14		
	15a		
	15b		
	15c	Manner: means	in such a way that
	16a		
	16b	Causal: result	so that
	17a		
	17b	Extension: addition	and
	18		
	19a		
Elaboration: expository	19b		in the sense that

	20a		
	20b		
	21a		
	21b	Extension: addition	and
	21c	Temporal: simultaneous	when
	22a		
	22b		
	22c	Conditional: concessive	although
	23a		
	23b		
Elaboration: verifactive	24a		in fact
	24b		
	25		
Paragraph 34	26a	Conditional: positive	If
	26b		
	27		
	28a	Conditional: positive	If
	28b		
	29a	Conditional: positive	If
	29b		
Conditional: concessive	30a		Although
	30b		
Causal: reason	30c		for the reason that
	30d	Matter: positive	where
	30e	Extension: addition	and
Extension: adversative	31a		By contrast
	31b	Conditional: concessive	even though
	32a		
	32b		
	33b		
	33c	Extension: addition	and
	34		
Extension: adversative	35a		However
Temporal: successive	35b		before
	36		

Note: According to Martin (1983:61) projecting clauses are not separate clauses for the purposes of conjunctive analysis.

The many explicit internal conjunctions in Raup and Sepkoski can be explained in relation to the authors' awareness of the importance of the readers (research community) relative to the writers and the consequent persuasive function of research articles. The authors use expository conjunctions (in bold face in what follows) to specify and justify their claims ([19a]*The illustrated composite cycle represents a best-fit to the data* [19b]***in the sense that*** *the composite peak…;* [24a]*The curve in Fig. 4 may* ***in fact*** *represent a rather conservative illustration of…*). They explicitly state their aims for the article ([12a]*The purpose of this paper,* ***therefore****, is to test the proposition of periodicity…*). They explicitly point out contrasts between the argument they consider reasonable and those they do not ([30c]*purely biological or earthbound physical cycles seem incredible…* [31a]***By contrast****, astronomical and astrophysical cycles of this order are plausible*). It is deference to readers that are not completely persuaded that leads the authors to end off the speculative paragraph with an adversative conjunction indicating that their own argument is unproved ([35a]*However much more information is needed* [35b]*before definitive statements about causes can be made.)*

Considering the external conjunctions, there are many conditional conjunctions in the extract as a whole and their preponderance is particularly marked in paragraph 34 where the authors are speculating. There are far fewer adversative conjunctions than in other texts. Only twice do the writers explicitly oppose their argument to that of other researchers ([9]*There is increasing evidence, **however**, that many extinctions are actually short-lived events* ..; . [31a]***By contrast**, astronomical and astrophysical cycles of this order are plausible*...). Causal relations are for the most part not realised conjunctively in this text, but rather clausally as witnessed by the preponderance of identifying processes especially in clauses 19 to 36 (see tables 4.1.8 and 4.1.9 above).

4.1.2.5 Summary and overview of Mode in Raup and Sepkoski

Raup and Sepkoski, as the reader will see later, is similar to two of the popular texts (the Scientific American and the Mail and Guardian articles). This is so because these three texts show most evidence that the message has been organised, through theme and conjunctions, with a view to directing the interpretation of the reader. The text, which is a highly impersonal text in general, uses interpersonal themes combined with textual themes and β clauses as theme to track the argument and make it clear and credible to the reader. These marked themes support Myers' (1989) contention that research articles, although apparently objective, actually have a persuasive function in that they must convince the research community in the person of the reader to accept their knowledge claim. A further example of the authors' directing reader response is their use of conjunctions. Raup and Sepkoski is the only text in the study to use many internal conjunctions and, as with the use of marked themes, this can be explained in terms of the persuasive function of research articles and the authors' subsequent need to direct the argument explicitly.

Raup and Sepkoski is a highly abstract text with a considerable amount of nominalisation and with processes construed as nouns and logical relations construed as verbs. Both nominalisation and passivisation are employed to remove people from the account and thus, in the value system of science, to achieve an impression of objectivity. The passive is also employed for reasons of politeness to the research community as represented by the writers (for example omitting other authors when the writers are disagreeing with them). Further, the passive is used to bolster the authors' own case (for example making their own argument appear general by claiming it had "[4]*previously been linked to…*"). Embedded clauses in this text allow the writers to package central propositions into facts whose credibility the ranking clause can either bolster or reflect negatively on. Much of the other embedding in the text adds to the nominal group information of a greater level of specificity than that found in the ranking clause. Altogether the organisation of the message points to a highly written, abstract impersonal text, which nevertheless succeeds in being persuasive through skilful use of marked theme and conjunctive relations

4.1.3 Tenor in Raup and Sepkoski

Tenor, as explained in 3.2.5, refers to the roles of the reader and writer of a text and interaction between them. In this section I consider the categories of contact, affect and status, hedging, and evaluation.

4.1.3.1 Contact, affect and status in Raup and Sepkoski

In what follows I consider the first three of the categories mentioned above, contact, affect and status, three categories which Gerot (1995:104) uses to illuminate the interpersonal metafunction.

Contact in Raup and Sepkoski

Contact refers to writer's solidarity with readers (Gerot 1995:104). The high level of nominalisation, passivisation, and use of technical language, as I have already pointed out, make this text very formal. Within the context of the research article genre, these features in themselves also display solidarity with the reader. Solidarity with the reader is also indicated by reader-oriented hedges (see section 4.1.3.2), and by the strict adherence to conventions such as referencing. The projected readership of the Raup and Sepkoski article is researchers in the same field, although, as Myers has pointed out (cf. section 2.3.3.4), a wider readership that can be loosely thought of as the scientific discourse community (i.e. all fields) is a secondary readership that must also be taken into account. The attitude to science in Raup and Sepkoski is positive. There is no question that quantitative statistical methods can be fruitfully employed to arrive at a reliable model of what has happened in the past, although Raup and Sepkoski does not claim that it has done so.

A graph is included in the extract from Raup and Sepkoski (see appendix page 5). Graphs, classified by Kress and van Leeuwen (1996:104) as spatio-temporal analytical images, are highly abstract analytical structures. Graphs are not naturalistic, and the particular graph in Raup and Sepkoski needs a high level of understanding of statistics to decode. The presence of this graph means that the writers extend solidarity through this graph to those of their readers who have this high level of understanding of statistical methods. They assume their readers fall into this group.

Affect in Raup and Sepkoski

Affect refers to 'positive or negative attitude of the writers to the readers and what they are talking about' (Gerot 1995:104). Scientific language is usually characterised as having little or no attitudinal lexis. There is a fair amount of attitudinal lexis in this article, but it is very subtly expressed. In the Introduction paragraph, previous studies are subtly hinted to have been overly simplistic through the use of mood adjuncts (which I have bold-faced in what follows): these studies have [7a]***generally** assumed* ..., they have viewed species as [7b]***always** at risk*, and [7c]*mass extinctions as **simply** reflecting*... By contrast, Raup and Sepkoski's research seeks to show that many extinctions are [9]***actually** short lived events.* The present study is thus to be a more accurate assessment of what is actually the case, not based on over-simplification and assumptions. For example, Fischer and Arthur (which Raup and Sepkoski agrees with) used a [11a]*limited data base* and [11b]*no statistical testing*. Raup and Sepkoski, by contrast, aims to use [12b]*a rigorous methodology*.

Attitudinal lexis is also found in the Implications section. Here an explanation the authors favour is said to be [31a]*plausible* while one they do not favour seems [30c]*incredible*. Also, the authors refer to themselves as "[30b]*favouring*" a particular option.

Status in Raup and Sepkoski

Status refers to how the writer includes the reader (Gerot 1995:104). As pointed out by Myers (1989) there is a need in research articles to show politeness and deference to the research community, which is represented by the readers. This is achieved by solidarity politeness (see reader-oriented hedges in section 4.1.3.2 below). This solidarity politeness is necessary, Myers (1989) argues, because the assumption is that the individual researcher is much less powerful than the research community. Thus, unusually amongst this selection of texts, the reader is assumed to be more powerful than the writers are. The writers make the text very acceptable to the readers by sticking closely to the conventions of the discourse community: the various sections of a science research article, (introduction, method, results, and discussion) as well as the referencing conventions.

4.1.3.2 Hedging in Raup and Sepkoski

In this section I look at the hedging in Raup and Sepkoski. Hedges express tentativeness and can either be used to show a writer's lack of commitment to a proposition or a desire not to express commitment (Hyland 1996a: 478).

Table 4.1.14: Hedging in Raup and Sepkoski

22a	*It should be noted* that the composite curve in Fig 4 rises to a fairly sharp peak, which is compatible with (although does not prove) the proposition that mass extinctions are discrete events	Reader-oriented hedge. '*Should be noted*' denotes obligation. The imperative form is an FTA, which is offset by the passive (i.e. person doing the ordering and person being ordered are not explicit). In the context of this article this is a very marked form because imperative.
23b	*If* extinctions resulted from continuous fluctuations in background rate, a composite curve approaching a sine-cosine function *would be expected.*	A reader-oriented hedge Passive: who would expect? Writers/readers/scientists/people in general. It invites reader participation. The modal signals that because continuous fluctuations (which most readers probably support) is not reflected in the graph, the concept must be wrong. Combined with the conditional If ... this is a polite way of indicating that an accepted idea is wrong.
24a 24b	The curve in Fig. 4 *may in fact represent* a rather conservative illustration of the abruptness of the average extinction peak; much of its breadth *may result* from the interval nature of the data	I regard these as reliability hedges: the writers do not really know but are providing as accurate an assessment as possible of the reality they describe
26a	*If* periodicity of extinctions in the geologic past *can be demonstrated*	This modal verb, combined with conditional *If* ..., is a reader-oriented hedge (mitigates FTA to readers whose research has shown no periodicity).
30a	Although none of these alternatives *can be ruled out* now,	This is either a reliability hedge (writers really cannot rule out these alternatives) or a reader-oriented hedge (mitigates FTA to readers by not limiting their options). May play both roles - as hedges are a "fuzzy set" (Hyland 1996c:438)

33a 33c	Shoemaker has argued (21) that passage through galactic arms *should increase* the comet flux and this *could*, following the Alvarez hypothesis (22) *provide* an explanation for the … extinctions	In Halliday's (1994) terms *should increase* indicates obligation; *could provide* indicates probability. In this context these are both a way of indicating prediction. I read both of these as a writer-oriented hedges - both Alvarez and Shoemaker are cited to back up the authors' claim
35b	However much more information is needed before definitive statements about causes *can be made*.	A reader-oriented hedge: they desire to mitigate the FTA of proposing an explanation at odds with the research of many readers who are in the same field, so the authors limit the extent of their claim
36	*It may turn out* that the biological record is sensitive to periodic phenomena	A reader-oriented hedge: the writers leave the readers with some options and point out that their own interpretation may be partly wrong.
5b	Although the causes of the periodicity are unknown , *it is possible* that they are related to extraterrestrial forces	A reader-oriented hedge: most research has not reached this conclusion so most readers will not agree with this; the hedge mitigates the threat to the face of readers.
6a	*Virtually* all species of animals that have ever lived are now extinct	Reliability hedge
8a	*Following this view*, the extinction process is often described as a time homogeneous process using …	A writer-oriented hedge: the writers distance themselves from an explanation with which they do not agree
10a	Fischer and Arthur (4) departed from convention by arguing that …	A writer-oriented hedge?
22	… the composite curve in Fig 4 rises to a fairly sharp peak, *which is compatible with (although does not prove)* the proposition that	A reliability hedge: writers seek to state very precisely the extent to which fig 4 corresponds with their central knowledge claim
27	*A first question* is whether *we* are seeing the effects of a purely biological phenomenon ...	A reader-oriented hedge: the writers invite reader involvement
28a	*If* the forcing agent is in the physical environment, does this reflect an earthbound process or something in space?	Question invites reader involvement: reader-oriented hedge. Also makes their favoured option conditional
29a	*If* the latter, are the extraterrestrial influences solar, solar system, or galactic?	The question invites reader involvement: reader-oriented hedge. It also makes their favoured option conditional
30b	*we favour* extraterrestrial causes.	Reader oriented hedge: the authors stress that this is just their preference. Readers are given options.
32a	*One possibility* is the passage of our solar system through …	Reader-oriented hedge: gives the reader options
35a	However much more information is needed	Reader-oriented hedge: admitting own limitation in knowledge.

The analysis in Table 4.1.14 above indicates that more than half of the hedges in the analysed text are reader-oriented (i.e. function in mitigation of face threatening acts to readers). Not surprising is the fact that most reader- as well as most writer-oriented hedges are in the Implications section: this is the section where the writers speculate and have little or no evidence for what they say. They want to mitigate the FTAs of these speculations and not be held accountable for some of the unconventional suggestions they make It is also unsurprising that most content-oriented hedges are in the Discussion section, since it is here that the authors assess the extent to which their data can be explained by their model. Any deviations from this are likely to be expressed as reliability hedges Table 4.1.15 contains a count of the kinds of hedge in each section of the article.

Table 4.1.15: Summary of hedging in Raup and Sepkoski

Hedges	Abstract	Intro	Results	Method	Discussion	Implications	total
reader-oriented	1				2	10	13 59%
writer-oriented		2				2	4 18%
attribute hedges							0
reliability hedges		1			3		4 18%
fuzzy-set reliability or reader-oriented?						1	1
total	1	3			4	13	22

My analysis of textbooks and popular articles in the rest of chapter 4 will show that research articles are unusual in containing many reader-oriented hedges. This difference between research articles and other science writing reflects the different power relations in these different texts. As mentioned above, in research articles the reader (research community) is more powerful and must be persuaded to accede to the writers' knowledge claims. If this attempt at persuasion is successful, the knowledge claim will be transformed into a fact. In textbooks, as I show in the next section (i.e. 4.2), the situation is reversed, and it is the writer who, in summarising the accepted knowledge (facts) of the research community, is the powerful representative of that community.

In summary, this section supports Myers' (1989) finding of writer deference to the research community in research articles, through what Hyland (1996) refers to as reader-oriented hedges.

4.1.3.3 Evaluation in Raup and Sepkoski

Evaluation, the focus of this section, is a category that includes all meaning that functions to express the writer's opinion and value system, and construct and maintain relations between writer and reader (Thompson and Hunston, 2000:6). I begin in Table 4.1.16 by considering evaluation in each clause (cf. section 3.2.5.4).

Table 4.1.16 Evaluation in Raup and Sepkoski following Hunston (1993, 1994)

Cla use	Activity	Source	Modification	Certainty	value	
Paragraph 1						
1a	event	writers		certain	+ accuracy	comprehensive
1b	event	writers		certain	+ accuracy	comprehensive
2a	event	writers		certain	+ accuracy	comprehensive
2b	result	writers		certain		
3	result	writers		certain	+ reliable	certainty
4	result	writers		certain	+ reasonable	fit to other facts
5a	hypothesis	writers	unknown	unknown		
5b	hypothesis	writers	possible	possible	**Hypothesis ET**	
Paragraph 2						
6a	state fact	accepted information		certain		
6b	state fact	accepted information		certain		
7a	hypothesis	accepted information	generally assumed	probable	**hypoth gradualism**	
7b	state fact	accepted information		probable		
7c	hypothesis	accepted information	simply	probable		
8a	state fact	accepted information	following this view	probable		
8b	event	statistical methods		probable		
9	hypothesis	writers	increasing evidence	probable	**hypoth catastrophism**	
10a	narrate event#	citation		certain		
10b	project					
10c	hypothesis	citation	arguing	possible	**F&A hypothesis (peridicity 32ma)** + *reasonable*	
10d	result	citation		certain	+ *reasonable*	fit to other facts
11a	assess	writers		certain	- accuracy	comprehensive
11b	assess	writers		certain	- accuracy	comprehensive
12a	hypothesis	writers		certain	**Hypothesis Periodicity (26ma)**	
12b	event	writers		certain	+ accuracy	comprehensive
Paragraph 27-29						
13	describe figure	writers		certain	**figure**	
14	describe figure	writers		certain		
15a	event	writers		certain		
15b	event	writers		certain		
16a	event	writers		certain		
16b	event	writers		certain		
17a	event	writers		certain		
17b	event	writers		certain		
18	event	writers		certain		

19a	describe figure	writers		certain	*+ consistent*	fit to data
19b	describe figure	writers		certain		
20a	result	writers		certain	*+ reliable*	certainty
20b	result	writers		certain	*+ reliable*	certainty
21a	assess	writers		certain	*- reliable*	
21b	interpretation	writers		certain	*- reliable*	
21c	interpretation	writers		certain		
22a	interpretation	writers		certain		
22b	interpretation	writers		probable	+ supportive	fit to theory
22c	interpretation	writers		probable		
23a	interpretation	writers	if	unlikely		
23b	interpretation	writers	would be expected	unlikely	- supportive	not fit to theory
24a	interpretation	writers	may represent	possible	+ reasonable	fit to other facts
24b	interpretation	writers	may result	possible		
25	interpretation	writers		certain		
Paragraph 34						
26a	interpretation	writers	If...can be demonstrated	possible		
26b	interpretation	writers		certain		
27	hypothesis	writers	whether	unknown	**hypothesis earthly**	
28a	hypothesis	writers	If	possible		
28b	hypothesis	writers	?	unknown		
29a	hypothesis	writers	If	possible		
29b	hypothesis	writers	?	unknown	**hypothesis ET**	
30a	assess	writers	can be ruled out	certain		
30b	assess	writers	favour	probable		
30c	assess	writers	seem incredible	unlikely	- accuracy	fit to data
30d	assess	writers		certain		
30e	assess	writers		certain		
31a	assess	writers	are plausible	possible	*+ useful*	
31b	assess	writers		certain	*- accuracy*	explicatory power
32a	hypothesis	writers	possibility	possible		
32b	state fact	citation	estimated to occur	possible		
33a	project					
33b	hypothesis	citation	argued, should increase	possible		
33c	hypothesis	writers	could provide	possible	+ useful	explicatory
34	state fact	accepted knowledge/ unspecified citations		certain	*+ reasonable*	
35a	recommend	writers		certain	*- accuracy*	comprehensive
35b	recommend	writers		certain		
36	hypothesis	writers	may turn out	possible		

Close analysis of evaluation in Raup and Sepkoski reveals that, in terms of status, the writers are the source of almost every clause. This is very different from the source of information in the other genres. As might be expected, items with the status of event or result are always certain. The writers are certain about what they did, and about their description of results. It is only the interpretation of results and the writers' hypotheses about which they show any degree of uncertainty. Hypotheses may be unknown (such as their own hypothesis of the extraterrestrial cause of extinction), possible (such as Fischer and Arthur's hypothesis of periodic extinction), or certain (such as their own hypothesis of periodic extinction). Most of what the writers say in this article is certain. Only in the Implications section does much of what they say become unknown, and possible, with some items being evaluated as probable. No items with which the writers agree are evaluated as unlikely.

Interestingly, in reviewing the literature (which Raup and Sepkoski does in the second paragraph), it is quite clear that the writers believe the assumptions of the literature to be wrong. Yet these assumptions are not evaluated as unlikely or untrue, but rather as probable. An example is located in clause 7a-8 in which instead of negatively evaluating the gradualism hypothesis as unlikely or untrue, it is merely juxtaposed to (placed immediately before) the catastrophism hypothesis which is positively evaluated as reasonable.

Raup and Sepkoski advances two main hypotheses: periodicity of extinction, and secondly, an extraterrestrial cause for these periodic extinctions. The first of these is well supported with data, but the second is not, and is actually a speculation, which is found in the Implications section of the article. In terms of Value, the first hypothesis is positively evaluated as [10]reasonable (showing a fit to the findings of other researchers, Fischer and Arthur), [12]accurate (the study being comprehensive in method), [19a]consistent (the findings showing a good fit to the data), [20]reliable (the statistical tests indicating a high level of certainty), [22b]supportive (the results being compatible with the hypothesis), [24a]reasonable (when the incomplete nature of the fossil record is taken into account) and finally, important.

These evaluations are repeated in summary in their abstract where the authors stress the [1]accuracy (comprehensiveness) of the methods, the [3]reliability (statistical significance) of the results, and the [4]reasonableness of the claims (in that they are supported by previous findings/claims). Interestingly the first three sentences of the Abstract state the central hypothesis/knowledge claim of the article in terms of events and results rather than hypothesis or interpretation of results. This knowledge claim/hypothesis thus appears in the abstract to be entirely certain, rather than tentative and open to question.

The second, and less well supported, hypothesis of the article, that the extinctions may have an extraterrestrial cause, is dealt with only briefly. This hypothesis is positively evaluated as useful (in having explicatory power) and as reasonable (in being supported by previous ideas on the subject). However, it is negatively evaluated for accuracy, since it lacks comprehensiveness.

The ideas of others are more likely than the authors' own ideas to be assigned negative value by Raup and Sepkoski. For example, although the purpose of citing Fischer and Arthur is to give weight to the authors' own study, it is negatively evaluated for accuracy (in that their data and methods were not comprehensive). Thus Fischer and Arthur's study also functions to point to the gap in the field (Swales 1981), a gap which the Raup and Sepkoski study fills. Similarly, options that they did not choose are negatively evaluated by the writers. For example the idea of extinctions as gradual rather than periodic is not supported by the findings of the study:

> [23a]*If extinctions resulted from continuous fluctuations in background rate,* [23b]*a composite curve approaching a sine-cosine function would be expected.*

In summary, the analysis of evaluation in this section reveals a text where negative evaluation is sparingly used. On the one hand the writers want to convince readers of the reliability of their methods and the truth of their own knowledge claims; on the other hand they are motivated to evaluate the ideas of others positively out of deference to the research community. The writers' own methods, results and hypothesis of periodic extinction are evaluated as certain. Only their hypothesis of an extraterrestrial cause of extinction is unknown. In line with the aim of deference to the research community, the assumptions of the literature with which the writers disagree are evaluated as probable rather than unlikely. A study with which the writers agree is negatively evaluated for accuracy to indicate a gap in the field, which the writers fill in the present article.

4.1.3.4 Summary and overview of Tenor in Raup and Sepkoski

My analysis of tenor in Raup and Sepkoski reveals a text that is, on the one hand, abstract and impersonal, while on the other hand it is highly persuasive. The abstractness of the text is reflected in the level of statistical analysis in the text and in aspects such as the graph, to understand which a fairly high level of understanding of statistics is required. The impersonality of the text promotes the appearance of objectivity through removal of people by the use of passive constructions and nominalisation. The persuasiveness of the text is achieved through evaluation and hedging, but also through some use of attitudinal lexis. The authors are writing for a small group of researchers interested in the same field of research as themselves, but also need to take account of the rest of the research community who may take an interest in the work (Myers 1989). The readers are the representatives of the research community and as such they must be treated with solidarity politeness in order to persuade them to accept the findings of the article. The authors do this partly through the impersonality, and 'objectivity' of the text, which in the cultural context of science increases its truth-value, and partly through such devices as reader-oriented hedges. Negative evaluation is sparingly used as the writers have no wish to evaluate their own methods and findings negatively and out of deference to the community they do not evaluate the ideas of others negatively even when they disagree with them.

4.1.4 Summary and overview of Register in Raup and Sepkoski

In chapter 2, I discussed how Halliday (1993:56) describes the scientific register as recognisable because of the effect of "clusters of features". Amongst these are nominalization of verbs and adjectives, extended nominal groups, a high proportion of relational processes, technical terms, tentative language, causal and reasoning verbs, impersonal language and passivization. These features are found to a marked degree in Raup and Sepkoski. Section 4.2, which focuses on university level textbooks, will show that textbooks are very similar to this research article in terms of register

Raup and Sepkoski employs embedded clauses to extend the nominal group to increase the level of specificity of what is said, and to package central propositions into facts. These are often imported from other texts and are often subjected to evaluative commentary sited in the ranking clause Relational clauses are twice as common as material clauses in this text, and section 4.2 will show that these are likely to be common in textbooks as well. Attributive processes attribute characteristics while of the identifying processes, most show relations of equivalence, with cause also being realised through identifying processes rather than through the more congruent choice of conjunctions.

In Raup and Sepkoski, human participants are removed from the account through the use of the passive voice and nominalisation. This functions to establish that what is being said is objective. As discussed in chapter 2, establishment of information as factual and objective involves removal of time, place and the people from whom the information originated. Raup and Sepkoski remove themselves as agents, and thus use the passive, to make their knowledge claims appear as objective as possible. They remove other researchers for reasons of politeness: to avoid disagreeing with them (clause 7 and 8) or they imply that ideas they agree with are widely accepted by not attributing these ideas (clause 9).

The writer of the research article has the difficult task of appearing objective while at the same time persuading the reader to accept the knowledge claims of the article. To appear objective writers of research articles must avoid the usual means of persuasion - personalising the message and using overt attitudinal lexis. Part of the persuasion of the genre lies in the appearance of objectivity (including removal of people), because an appearance of objectivity is in itself persuasive to the particular group of readers to which science writing is addressed. Beyond this, persuasion is also found in subtle features such as hedging, evaluation and very subtle attitudinal lexis.

4.1.5 Genre in Raup and Sepkoski

Genre (cf. section 2.3.1) is what Thompson (1996:36) calls 'register plus purpose...what the interactants are doing through language, and how they organise the language event in order to achieve that purpose'. In broad terms, in a research article the writer is trying to get his/her knowledge claims recognised as fact. To achieve this, as discussed in chapter 2, research articles generally follow the Introduction-Method-Results-Discussion structure. To which Raup and Sepkoski adds a final Implications section. Bazerman (1988) (cf. the account given in section 2.4.1) discusses how the structure of the research article has grown up to convince readers who have not themselves observed the work described in the research article that the authors carried out the work in an acceptable manner and add something new and useful to previous work in the field. Bazerman (1988) has shown further that these four sections function to persuade the reader: the Introduction places the work done within the context of other research in the area, and ideally it shows that the work described is continuous with previous work done in the field. The Method section tries to convince the readers that the work was done in a way consonant with the methods of research science: free from distortion, fit to observation, and close to non-lab conditions (Hunston 1994). In the Results, usually represented as a graph, table or else mathematically, the writers aim to convince the reader of the relevance, significance and repeatability of what they have done (Hunston 1994). The Discussion tries to convince the reader of the writers' interpretation of the results, that it has explicatory power and is fit to expectation (Hunston 1994).

In the case of Raup and Sepkoski, the Abstract is a summary of the research article: clause 1 and 2 summarise the Method, clause 3 and 4 summarise the Discussion section, and clause 5 summarises the Implications section.

The Introduction is, from the perspective of the Australian school (e.g. Butt et al 1999:20) a *discussion*: clause 6 is an introductory statement, clauses 7-8 contain arguments on the side of gradualism, clauses 9-12 contain arguments on the side of catastrophism. The authors juxtapose these two arguments and place them in explicit opposition to each other by use of the adversative conjunction '*however*' in clause 9 They aim to show that although not in agreement with gradualism, they follow on the tradition of workers such as [10a]Fischer and Arthur, but fill a gap by using more rigorous methods

The **best fit cycle** (Method section) is a recount (Butt et al 1999:18): clauses 13-14 contain the orientation and clauses 15-18 present how the authors did the research and what they did, in the order in which it was done. The authors remove themselves from the account by the use of agentless passives, attempting as far as possible to indicate that what was done is repeatable and not dependant on time place or person.

The Discussion is *exposition* (Butt et al 1999:21): clause 19 is position statement, and clause 20-25 is a series of reasoned arguments supported by evidence. The authors attempt to persuade the readers that their own results are reliable and fit their theory, (see my analysis of evaluation and table 4.1.16). They try to convince the reader that other interpretations of the data are not reliable:

[21a]*Other cycle lengths give less significant results* [21b]*and the composite curve deteriorates into an irregular, non-unimodal curve (noise)* [21c]*when the cycle departs substantially from the best-fit cycle.*

Finally, the Implications section has elements of *discussion* and *exposition*. It is briefly set up as discussion in clause 26-29 with two sides of an argument presented. However in clause 30-36 it becomes exposition with the authors arguing for their opinion (an extraterrestrial rather than earthly cause of mass extinction).

As this article is not unrepresentative of research articles in general, we can conclude that research articles contain *discussion*, *recount* and *exposition*, but that these are likely to be associated with particular sections.

This brief discussion of genre in Raup and Sepkoski has thus shown that, as indicated by Bazerman (1988), all sections of the article work together to persuade the reader to accept the writers' contention, in this case that mass extinctions [3]*show a statistically significant periodicity (P < 0.01) with a mean interval between events of 26 million years*. The Introduction shows the reader that the work is situated in a tradition of similar work but that it also fills a gap in previous research. To persuade the reader of the repeatability of the work and that it is not peculiar to the researchers, the Method describes what was done. The Discussion presents arguments to show how the results can be explained by the writers' hypothesis that mass extinctions have occurred every 26 million years.

4.1.6 Ideology in Raup and Sepkoski

In the Raup and Sepkoski article the world-view projected is one which combines mundane exactness with, from any perspective but a modern scientific one, a strong, but never admitted, element of the fantastic. The world of the article is one in which precise quantification of the deaths of remotely distant organisms is possible. The deaths of these organisms are mapped not only onto the fossil record over an unimaginably large time scale, but onto graphs, and subjected to the [12b]*rigorous methodology* of statistical tests. As pointed out by Latour and Woolgar (1979) and Pinch (1985), evidence in science is often at several removes from what is being proved. It is impossible to measure mass extinction directly, so the rate at which species died out becomes the measure of this. Once again this is impossible to measure directly, so the measure of fossils becomes the measure of this. This is tested statistically, introducing a further remove from what is being measured.

In the uncertain disaster-ridden world of the article, the idea that [6a]*virtually all species of plants and animals that have ever lived are now extinct*, (first sentence of the Introduction) is presented as unremarkable and uncontested fact (no citations necessary to support this idea, and it is unhedged). As partially new information the reader is told that these extinctions are likely to have happened as massive periodic extinction events. The tone in purveying all these ideas is entirely factual, and unexaggerated. Authorial presence is almost absent, and human participants are few. Authorial presence is felt only in the final section, which makes the even more fantastic suggestion of an extraterrestrial cause for periodic mass extinction. In spite of modality and hedging, this final section remains factual and understated. The authors entirely ignore the sensational, 'newsworthy' potential of what they say. The field has similarities with that of many disaster films, but the mode and genre could not be more different.

The text is factual in tone, and for the most part what it says is factual in the sense of being well supported by evidence Facts are meticulously backed up with evidence: either data, statistics or citations; there is no instance of appeals to undefined authorities as in "it is well known that" or "scientists now accept that..." However fact as belief is not excluded from the article ("[30b]*We **favour** extraterrestrial causes*"). The use of extensive hedging in the Implications section allows the writers to advance ideas that are belief or speculation rather than knowledge.

At the interpersonal level, the article is very impersonal. In the world of the text personal language is a signal of weakness at the level of either reasoning or evidence. There are three functions served by personal language in the article. One of these is achieved through citations. From one point of view these can be said to bolster the writers' case (which implies a perception of weakness in their argument by the authors). From another viewpoint citations are not a sign of weakness; crediting ideas to their originators is necessary; if the writers failed to cite the origin of ideas this would be akin to claiming them for themselves and would not be tolerated by the discourse community. A second function served by personal language in the article is the solidarity politeness in **we** in clause 27. This has been viewed by Myers (1989) as an attempt to draw the reader into an idea/viewpoint, elicit the reader's involvement in an idea/viewpoint. Once again this can be interpreted as stemming from the authors' perception of weakness in their argument. The third function served by personal language is limitation of belief to the authors, once again, as Myers (1989) points out a sign of weakness of argument in that the authors feel it would be interpreted as an FTA if they assumed that readers shared the belief.

The intended readers of the article are a highly select group in a number of ways. Firstly, the readers are a group who can decode the specialised language of the article. This includes, most importantly, the statistics, but also the technical terms, the high degree of nominalisation, and the meaning of the interpersonal language, including solidarity politeness. The readers are people who do not read the article as a dry-as-dust account of a story that would have been sensational if differently told, but rather as an interesting addition to an area of research they are already familiar with: 'the Alvarez hypothesis' of an extraterrestrial rather than earthly cause for extinction. Much is not made explicit in the article so the readers share with the writers a number of concepts and beliefs about the nature of the world, its age, evolution, the fossil record, the geological record, etc. However the intended readership is even narrower than this: the intended audience of the article seems to be those geologists, palaeontologists, biologists and astronomers who are working in this particular field.

In summary, this article confirms the characterisation of the research article by Myers (1989) and Bazerman (1988) as persuasive in function. The purpose of the article is to gain acceptance by the research community (represented by the reader) of the idea of periodic mass extinction at intervals of 26 million years. To be persuasive Raup and Sepkoski must conform to the ideology of science in which impersonality implies objectivity because it removes individual people and particular instances of time and place from the account and makes the knowledge claim universal and factual. To be persuasive they must also show deference to the community. This involves the writers in the difficulty of being objective and impersonal while being persuasive (usually achieved subjectively). This the writer of a research article solves through solidarity politeness (reader-oriented hedges), subtle attitudinal lexis, and subtle evaluation found in modal adjuncts, modal verbs and attributions.

4.1.7 Summary of the chapter

As Myers (1989) has pointed out, the reader of a research article represents the research community, which is more powerful than the individual researcher i.e. the writer. The research article thus needs to persuade the reader to accept the writer's argument. Such persuasion is achieved in research articles, unusually, through writing that is highly impersonal, objective, and abstract. Impersonality in Raup and Sepkoski is achieved through the dearth of human participants combined with the high level of nominalisation and passivisation. This impersonality, combined with features such as packaging significant propositions and hypotheses into fact clauses (making them less negotiable) creates an impression of objectivity. Abstraction is evident in the fact that most meaning is construed through identifying rather than material processes, the high level of nominalisation with processes construed as nouns and logical relations construed as verbs, the technical and statistical language used, and the fact that the only 'illlustration' is a highly abstract and objective form, the graph.

Because of the cultural context of a research article I argue that the impersonality and objectivity of the text function to persuade the reader that the writer is being objective and factual. Because objectivity is an ideological necessity in science it contributes to persuade the reader that what is said is true. Besides this, persuasion is evident firstly in the thematic development in which marked themes are used to guide the reader in what is important in the writers' argument, and use of internal conjunctions to guide the reader to accept the writers' explanation. It is also achieved in attitudinal lexis and also in various ways of being polite to readers. These include solidarity with readers in use of technical language, use of reader-oriented hedges such as omission of agent when the writers want to criticise the ideas of other researchers, sparing use of negative evaluation of their own work or that of others, and strict adherence to the conventions of the research article.

4.2 The textbook genre: An extract from a first year geology textbook, including comparisons with a textbook for advanced students and a textbook for non-scientists.

4.2.0 Introduction

In my examination of textbooks as a genre, I began by analysing extracts from three textbooks in detail. These three textbooks were selected as being pitched at different levels and at different groups of readers. The first textbook, and the one I treat as exemplary and examine in detail in this section, is a first year geology textbook, which, as with Raup and Sepkoski before, I refer to by its author's surname: Duff. The reader can consult the entire original text of the article by folding out page 9-11 of the appendix. A second textbook, by McGhee (pages 13, 15 and 17 of the appendix), is a textbook for more advanced students of geology, those in their second or third year of study, or even at postgraduate level. The third textbook, by Trefil and Hazen (appendix pages 19 and 21), is an unusual textbook in being written for non-scientist students in a 'Great ideas in Science' course. These three textbooks show many similarities, with similarities between Duff and McGhee being especially marked. Therefore, for reasons of economy, and to avoid repetition, I have chosen to focus on Duff. I refer to McGhee and Trefil and Hazen only where they differ from Duff. Differences between the three textbooks can be explained largely in terms of their different readers. That is, differences are largely interpersonal.

As in my discussion of the research article genre in section 4.1, in this section I consider the context of situation, or register, of the textbook by analysing the text in terms of Field (in 4.2.1), Mode (in 4.2.2) and Tenor (in 4.2.3). I then go on in section 4.2.5 to consider the context of culture, or genre, of the text, before moving on to a consideration of ideology in 4.2.6. The analysis indicates similarities between textbook and research article in terms of register. Like the research article, the textbook establishes objectivity (and thus high truth value) by removing people from the account. This is achieved through passivisation, nominalisation, extended nominal groups, use of technical language, and abstraction. Register diffeiences are, however, found at the interpersonal level in that, in contrast to the writer of the research article who is assumed to be less powerful than the reader, the writer of a textbook is an expert and thus relatively more powerful than the reader. Although similar at the level of register, research articles and textbooks are very different in terms of genre. As discussed in section 4.1.4, the research article most commonly follows the Introduction-Method-Results-Discussion structure, while the textbook combines a number of genres (used in this instance in the sense common in the Australian school) including Information report and Explanation.

4.2.1 Field in Duff

In this section I consider human participants separately before moving on to a consideration of processes, participants and circumstances. Because the function of the Duff text is to acculturate first year students into the discipline of geology, focus is not on extinction of the dinosaurs but, rather, on how theories of the nature of evolution, and the part played in this by extinction, have developed. This theme is developed in a highly abstract way, with material and verbal as well as relational processes expressing meaning to do with ideas rather than things or people. The abstraction and 'writtenness' of the text is increased by the siting of the discussion of the nature of evolution in clauses embedded in the nominal group and in circumstances. This makes these meanings less negotiable than if they had been sited in ranking clauses. The text is highly impersonal, with few human participants, and those human participants that are found are largely generic references to scientists. This reflects the ideology of textbooks, that ideas are more important than who discovered them. Within the culture of science the impersonality of the text also serves to increase its objectivity.

4.2.1.1 Human participants in Duff

As in the research article by Raup and Sepkoski, the paucity of human participants adds to the impersonality and apparent objectivity of this text. By contrast with Raup and Sepkoski, most of the references to human participants are generic: geologists and palaeontologists, both nineteenth century and present day. As discussed below (section 4.2.2.3, Passivisation), textbooks appear to contain all the findings that scientists make without the inclusion of the scientists themselves. The facts are central, not who discovered them. In an instance that is in my experience very unusual, the only human participant in a major specific role in Duff is the writer of a popular book/article [19]*the American writer S.J. Gould.*

Table 4.2.1: Human participants in Duff

3	one favoured early in the nineteenth century by French geologists in particular [*mental*]	Minor, generic
17	Some palaeontologists while accepting ... would resist [*mental*]	Major, generic
18a	many [palaeontologists] would maintain [*verbal*]	Major, generic
19	the American writer S.J. Gould has developed. [*material*]	Major, specific

McGhee, the textbook for advanced students, differs from Duff in that there are a number of specific human participants, although these are included in the highly impersonal form of citations. An example from McGhee is:

[29a]*Jablonski (1986a) noted that the Lazarus effect appears worst for the Late Permian event.*

This is a reflection of the more advanced level of reader for which McGhee is intended. Readers of McGhee are more advanced undergraduate or postgraduate students who may be referred to the texts most highly valued by the discourse community: research articles. This indicates the greater level of integration into the discourse community of these readers. Like Duff, the textbook for non-science students, i.e. by Trefil and Hazen, includes mainly generic references to scientists but, in contrast to Duff, also mentions Walter and Luis Alvarez as personalities (a geologist and ... a Nobel laureate in physics); it does not refer readers to their prestigious writings. In this it is similar to popular texts. In all three textbooks impersonality results from the fact that in textbooks, who first discovered an idea is of marginal importance compared to the idea itself. Researchers are uncoverers not inventors of reality. Latour and Woolgar's (1979) suggestion that how we construe reality plays a large part in our perception of what is real/fact is not recognised in this system of values, in which there is assumed to be an objective truth that can be uncovered given enough research.

4.2.1.2 Processes and participants and circumstances in Duff

In this section I report on the function of material, relational and verbal processes in this text. I consider extensions to the nominal group through embedding. Finally, I comment on the circumstances employed in Duff. I begin by listing the participants, processes and circumstances in Duff in Table 4.2.2.

Table 4.2.2: Processes, participants and circumstances in Duff

	Actor	**Material**	**Goal**	**Circumstance**
1	The stratigraphic use of fossils ...	may proceed		without any ... interpretation of ... evolution.
4	by notions of gradualism.	was challenged	catastrophism	with the emergence of evolution ...
5b		to arise		from ancestral stocks by gradual changes
5c	unsuccessful forms	died out		over variable periods of time.
7a	Palaeontological researches	have proceeded		with... intensity ... this century.
7b	many of the gaps ...	remain		in spite of these efforts
8		have been reinforced	the ...boundaries in the stratigraphic column	
9		is linked	a process ... called punctuated evolution	with modern support for catastrophism
10a	by mass extinctions	are ended	Long periods of little change in ... forms	
10b	by forms which have diversified ..	are taken over	the vacated ecological niches	
11		has been paid	Much attention to the K/T boundary (= beneficiary)	
13	by an enrichment in .. iridium.	is marked	the boundary	
18b	these reptiles	had been dying out		gradually for some time
19	by ... S.J. Gould.	has been developed	the case for mass extinctions by catastrophe...	recently in ... *Wonderful Life*
	Senser	**Mental**	**Phenomenon**	
5a		were thought	Diverse forms	
17	Some palaeontologists	would resist	catastrophism and instantaneous extinctions.	
	sayer	**verbal**	**Verbiage/range**	
6a		was maintained	It FACT	
15a		is maintained	It FACT	
16a		is debated	The topic	hotly
16b		is pointed out	It FACT	
18a	many	would maintain	that ... (FACT)	With regard to the K/T boundary

		Existential	**Existent**	
6a	there	were	gaps in the fossil record	with sudden changes in fossil content
	token	**intensive**	**value**	
2	the factors controlling ... change	have been (active)	the subject of debate ...	for the last two centuries
3	that of extinction by catastrophe	was (passive)	the simplest interpretation of the extinction ...	
15b	the catastrophic ... effects	being	the reason for much life ... becoming extinct.	
	token	**circumstance**	**value**	
12	examination of clays	has shown	some chemical and mineralogical peculiarities.	At a number of places...
14	in the fact that ... FACT	lies	The significance of this anomaly	

Table 4.2.3 below contains a count of the number of processes of each type and compares this to the numbers of each sort of process in McGhee, Trefil and Hazen, and Raup and Sepkoski. Most processes in this text are material processes, and in this, Duff is unusual when compared to the other three texts in table 4.2.3, which have double the number of relational processes compared to material processes. A greater number of relational processes is evidently more common in this register. This is confirmed by Halliday's (1994:65) discussion of the language of science.

Table 4.2.3 Processes in Duff compared to other textbooks and research article

	Material	Existential	Identifying	Attributive	Verbal	Mental	Behav	Total
Duff	14 (52%)	1 (4%)	5 (19%)		2 (7%)	5 (19%)		29
McGhee	15 (21%)	1	15 (21%)	25 (36%)	8 (11%)	5	1	70
Trefil & Hazen	10 (30%)	1	9 (27%)	6 (18%)	3	4		33
Raup & Sepkoski	16 (23%)	1	22 (31%)	16 (23%)	4	6	5	70

In broad terms, Duff is not about providing the reader with an account of the latest theories about what happened to the dinosaurs and what light this sheds on the rate of evolution. Instead it is concerned to "acculturate students into the mode of enquiry of the discipline and establish a cognitive model for the discipline" (Love 1991:91). The focus is thus on the development of theories of the nature of evolution and the role of the fossil record in this development. The writer is less concerned to provide detail than to sketch broadly the development of the discipline for the reader. It is thus the development of theories that is central in Duff, not the living things and how they were affected by an asteroid. Where the text does refer to living things, it is very detached; living things are in general referred to as '*forms*'. Even the theories themselves are held at a distance and referred to as [4]*notions*, [3]*interpretation*, [4]*idea*, [19]*the case*, [2]*the subject of debate*

Material versus relational processes in Duff

If we look at the material processes in this text, it is clear that the text is about the ebb and flow or growth and decay of ideas about the nature of extinction and evolution: *may proceed, to arise, died out, have proceeded, remain, have been reinforced, are ended, are taken over, had been dying out, has been developed.*

Material processes may reasonably be expected to deal with the physical world and to represent happenings in the real world; but almost all material processes in this extract focus on ideas, which we may reasonably have expected to see realised in relational processes. If we look at Table 4.2.3 we see that, of 15 material processes in the extract, only 5 (in clauses 5c, 10a, 10b, 13 and 18) deal with the real/physical world. Examples are: [5c]*unsuccessful forms died out*; [18b]*these reptiles had been dying out.*

On the other hand the material processes in clauses 1, 4, 7a, 7b. 8. 9, 11 and 19 actually deal with ideas and abstractions. Examples are:
[4]*catastrophism was challenged by notions of gradualism*; [9]*linked with modern support for catastrophism is a process which has been called punctuated evolution.*

So, although half of the processes are material, most of these material processes express meanings in the realm of ideas/abstract relations, not the physical world. They are similar in this to the identifying processes in the extract, and serve functions that would usually be construed though identifying processes i.e. the expression of ideas and concepts.

Verbal processes

The verbal processes in the extract are interesting in that three of the five (in clauses 6b, 15a, and 16b) are 'impersonal' projections where "the 'process' is not really a process at all, but simply a way of turning a fact into a clause" (Halliday 1994:271). They thus function to package information into facts. An example is:
[15a]*So it is maintained that the Earth was hit by an extra-terrestrial body.*
So verbal processes, like material clauses are used primarily to convey ideas rather than the utterances of people, which is their more usual function. Like the use of material

processes to convey abstract meanings, this use of verbal processes to convey ideas also contributes to the abstractness of this text.

Embedded material in Duff

A third element making this text abstract is the embedding of ideas on evolution within nominal groups and adjuncts. In fact, the writer never directly addresses the question of evolution and what it is. Instead evolution is discussed and elaborated on in embedded clauses. It is first mentioned in clause 1 in a circumstantial adjunct:

[1]*without any theoretical interpretation of the nature of evolution.*

The writer then proceeds to repeat the concept of evolution in different words no fewer than three times as embedded phrases (clauses 2, 3 and 4), and elaborates the meaning of evolution in a further four embedded clauses (clauses 5a, 7b, 9 and 10b):

[2]*the factors {controlling biological change}*
[3]*Perhaps the simplest interpretation {of the extinction of faunal and floral assemblages}*
[4]*with the emergence of evolution {as a dominating idea in biological change}.*
[5a]*gradual changes {imposed by physical conditions and biological competition;}*
[7b]*many of the gaps {{marking sudden extinctions followed by sudden increases in the number of forms (referred to as radiations)}}*
[9]*a process {{which has been called punctuated evolution.}}*
[10b]*by forms {{which have diversified in relatively isolated areas.}}*

Because discussion of the nature of evolution is embedded in nominal groups and adjuncts, the text is shot through with (embedded with) a discussion of the nature of evolution, but the topic is never directly addressed. Siting the discussion of evolution within embedded clauses makes it less negotiable. The reader is less able to challenge what is said about evolution. Only the ranking clause is available to challenge by the reader (Martin 2000b: 295):

[10b]*the vacated ecological niches are then taken over by forms ((which have diversified in relatively isolated areas)).* Are they? (not 'have they?')

This is not to imply that the writer expects any objection from the reader to the concept of evolution; rather the text is about the broad development of these ideas of evolution, rather than about evolution itself.

Citing this discussion of evolution in embedded clauses also makes the text much more abstract. The topic of the text is gradualism versus catastrophism, and these are direct participants in the text:

[3]*Perhaps the simplest interpretation ... was that of extinction by catastrophe.*

[4] *...catostrophism was challenged by notions of gradualism.*
However, if we wish to compare catastrophism and gradualism, it is our concept of evolution and which concept of evolution we find the more convincing model that is important. Ignoring all the embedded material would provide the skeleton of the text – that there are two sides to the debate, and what they are. However, if we want to understand the subtlety of the argument put forward by the text we need to take account of the embedded material.

In McGhee, the textbook for advanced students, the abstractness of the text is increased in a similar way. Like Duff, McGhee operates at one remove from its apparent topic: the Cretaceous mass extinction. The extract is not primarily about a meteorite impact cause for the Cretaceous mass extinction. These material meanings concerning real world events (e.g. mass extinction) are sited in clauses embedded in nominal groups and circumstances, indicating that the writer views them as non-negotiable/given/fact. Instead McGhee is about what various researchers have thought and said about the possibility that the Cretaceous mass extinction was caused by meteorite impact, and the evidence they have advanced.

Comparison with Trefil and Hazen
I have characterised both Duff and McGhee as highly abstract. In both these texts the writer is addressing readers who are to varying extents already 'members of the Discourse' (Gee 1990) of geology, and have some intention of becoming Geologists. However, it is worth mentioning that not all textbooks are like this. Trefil and Hazen represents the other end of the continuum of university textbooks. By contrast with Duff and McGhee, Trefil and Hazen is a textbook addressing non-science students who have no intention of becoming Geologists or 'members of the Discourse' of Geology Trefil and Hazen has some similarities with popularisations and books for children in that it is not abstract, has few technical terms or nominalisations, and is lexically simpler. It has little grammatical metaphor: unlike Duff and McGhee, the material processes in Trefil and Hazen congruently express meanings in the real physical world: these concern the asteroid hitting earth and its impact on living things. To a far greater extent than the other two textbooks, Trefil and Hazen is about happenings at the end of the Cretaceous rather than ideas or evidence. In this it is most like the books for children of the three textbooks. The mental and verbal processes indicate debate (compared to Duff where they are just as likely to express concepts), while the relational processes express quite a lot of

evaluation, with importance attached to being famous and amazing (values found in popular science texts). Thus this text shows some similarities to the popular texts in this study as well as sharing values with research science. Trefil and Hazen is more 'spoken' than the other two textbooks, having less passivisation and more human participants. We can characterise it as being to some extent a popularisation itself, as its projected readership is non-scientists.

Circumstances

As is found in other texts in this study, circumstances of duration ([5c]*over variable periods of time*), place ([12]*At a number of places throughout the world*) and manner ([5b]*by gradual changes imposed by physical conditions and biological competition*) are important. However, time is less prominent than in other texts presumably because the readers are presumed to have an awareness of this already. Unusually, circumstances of accompaniment are common, and three of these concern the very conceptual discussion in the text of theories of evolution ([1]*without any theoretical interpretation of the nature of evolution*; [4]*with the emergence of evolution as a dominating idea in biological change*; [9]*with modern support for catastrophism*). So in the circumstances in this text, as in other features, this analysis reflects Duff as a discussion of the development of ideas.

Table 4.2.4 Circumstances in Duff compared to other texts

	Duff	McGhee	Trefil & Hazen	Raup & Sepkoski
Extent: duration	**4 20%**	**6 22%**		2
Location: place	**3 15%**	**9 33%**	2	2
Location: time	2	2	**9 47%**	2
Manner	**4 20%**	3 11%	**4 21%**	3
Cause	1		1	
Contingency	1	1	1	
Accompaniment	**4 20%**	1		1
Role		3 11%		
Matter	1	1	2	
angle		1		
	20	27	19	10

4.2.1.3 Summary and overview of Field in Duff

This examination of processes and participants in Duff has shown that, compared to McGhee, Trefil and Hazen and Raup and Sepkoski, Duff has very few relational clauses, and a larger proportion of material clauses. However, a closer look at these material clauses indicates that most material clauses express meanings to do with ideas rather than with real world happenings or things. Duff therefore treats ideas as if they were things. Adding to the impression of the text as impersonal and lacking in human participants, there are few verbal or mental processes. Of the mental processes that there are, some are actually 'impersonal' projections – merely a way of turning a fact into a clause. A very interesting feature of this text is the way that meanings to do with evolution are embedded in extended nominal groups and adjuncts. Together with the fact that ideas (rather than happenings and utterances) are expressed in material and verbal processes, this makes Duff a very abstract text. The readers of this text, as first year geology students, are expected to have already attained a fairly high level of literacy in the discourse of geology, and the experience of reading Duff extends this literacy further. To be the reader that Duff projects, entails understanding lexically dense, abstract impersonal text. To a fairly marked extent, Duff 'recognises' the readers as 'members of the Discourse' (Gee 1990).

4.2.2 Mode in Duff

In this section, under the categories of theme, nominalisation and embedding, passivisation and conjunctive relations (precisely the same categories I employed in 4.1.2 in my analysis of Mode in Raup and Sepkoski), I report on the ways in which Duff has chosen to organise the message. My analysis shows that Duff uses both theme and conjunctive relations to emphasise to readers the distinctions he is making between ideas. On the other hand, through use of nominalisation and passivisation Duff buries the people behind the ideas making a highly impersonal and, thus, in the value system of science, objective text.

4.2.2.1 Theme in Duff

Duff uses marked topical themes (mainly 'heavy' themes and adjuncts) and contrastive textual themes to signal to the reader that there are many present and past voices on this topic. This is an area where consensus has not been reached by the scientific community.

Because there are equal numbers of passive and active processes in this text, a goal in thematic position cannot really be regarded as marked. So for the purposes of this text, I will not regard passivisation as associated with markedness.

Table 4.2.5 Theme in Duff

	textual	interpersonal	topical	Markedness*
1			The stratigraphic use of fossils {for purposes of correlating rocks ...}	'heavy' theme
2	But		for the last two centuries	Circum: time
3		Perhaps	the simplest *interpretation* {{of the extinction of faunal and floral *assemblages*, and favoured ... by French geologists ...}}	'heavy' theme; condition - hypothetical
4	On the other hand,		with the *emergence* of evolution {as a dominating idea in biological change,}	Circumstance: contrast
5a			Diverse forms	passive
5c			unsucessful forms	
6a	Wherever		**there were gaps in the fossil record with sudden changes in fossil content,**	β clause as theme
7a			Palaeontological researches	
7b	but		In spite of these efforts	Textual contrast
8	Thus		the major boundaries {in the stratigraphic column (see Table 7.1)}	Passive; cause
9			Linked with modern support for catastrophism	Marked pred and circum. in theme
10a			Long periods {of little change in widespread forms}	passive
10b	and		the vacated ecological niches	passive
11			Much attention	passive
12			At a number of places throughout the world, {{including the oceans, ...}}	Circ: place and 'heavy' theme
13	In particular		the boundary	Passive; adjunct: validation
14			The significance of this anomaly	
15a	So		it [verbiage]	cause
15b			the catastrophic and climate effects	
16a			The topic	passive
16b			it [verbiage]	Passive
17			Some palaeontologists	
18a			With regard to the dinosaurs and ...	circumstance
18b			these reptiles	
19	On the other hand		the case for mass *extinctions* by catastrophe {involving ... the survival of the luckiest}	Contrast; passive; 'heavy' theme

Notes on Table 4.2.5:

1. *nominalisation: italics*; **clause as theme: bold**; marked theme: underlined; { } embedded phrase; {{ }} embedded clause.
2. * In this column I signal the markedness of themes using Gosden's (1992) categories.
3. Double boundary lines indicate paragraphs

As noted in the analysis of transitivity in 4.2.1, this text is about ideas: what ideas people have had about evolution and influences on it over time, and how, when and why they

have changed them. The writer makes frequent use of marked themes to signal the stages of this argument and make the changes in ideas, and reasons for the changes clear to the reader. The writer starts in clause 1 with a marked heavy theme that posits one reasonable '[1]*stratigraphic use of fossils*'. That this is a use that is not to be the topic of the present discussion is immediately clear in the theme of the next clause, which is marked by both a contrasting conjunction and a circumstance locating the discussion in real time:
[2]*But for the last two centuries...*

In clauses 3 and 4 we have two opposing viewpoints and this opposition is marked with heavy themes in both clauses. In clause 3 we have a hypothetical conditional combined with a heavy theme. New material ([3]*and one favoured by French geologists in particular*) is imported into the theme, to further mark the clause and stress the group to whom this opinion was limited: [3]*Perhaps the simplest interpretation of the extinction of faunal and floral assemblages, and one favoured by French geologists in particular.*

Clause 4 is once again marked with a contrasting textual theme, and a conditional circumstance attached to this opinion: [4]*On the other hand, with the emergence of evolution as a dominating idea in biological change...*

Clause 5 continues the explanation of the argument started in clause 4. Clause 6, with a β clause in marked thematic position, alerts the reader to the possibility that what follows is a faulty argument:
[6]*Wherever there were gaps in the fossil record with sudden changes in fossil content.*

The theme in clause 7a maintains the idea of research set up in the preceding rheme, but in clause 7b, the reader is brought up short by two contrastive elements: a conjunction and a circumstance: [7b]*but in spite of these efforts.*

The textual theme '*Thus*' in clause 8 stresses the result of what was said in clause 7. Clause 9 once again has marked theme indicating emphatic addition. The theme of clause 10 explains the '*punctuated evolution*' from the previous rheme. A new element, the K/T boundary, is introduced in the rheme of clause 11. A marked circumstantial theme, foregrounding the site of findings about the K/T boundary, is found in clause 12. The topical theme of clause 13 maintains 'the boundary' as theme but the clause is marked by the textual theme, '*In particular*', which signals emphatic addition to the previous clause.

Clauses 14, 15, 16 and 17 are unmarked. Clause 18 has a circumstance, specifying the conditions of what follows, in marked thematic position:
[18]*With regard to the dinosaurs and K/T boundary*.
Clause 19 is marked by a textual theme contrasting what is to be said in clause 19 with what was said in clause 18.

Circumstances of time and place in marked thematic position are a strong feature of Duff. With these marked themes, Duff is concerned to sketch out in broad strokes for the reader the changes in ideas, and the reasons for these changes over time. These differences and changes are signalled by use of circumstances as marked themes and contrastive textual themes. These broad strokes are consonant with the fact that the readers are first year students and must be given a broad overview of the field. This contrasts with the McGhee text whose readers are students in later years. They already have the broad overview and, instead, are provided with a discussion of the evidence for the impact hypothesis in close detail. McGhee thus gives a detailed account of the research that has been done on the matter. The thematic development correspondingly alternates between maintenance of theme (keeping to the same theme as in the preceding clause) and progression of theme (selecting a constituent form the preceding rheme as theme) (Thompson 1996:141).

Thus on the whole, through use of marked topical themes, and of textual themes, many of which serve a contrastive purpose, the writer is at pains to signal to the reader the many 'voices' in the argument, who thought what, and what their reasons were. This stresses to the reader that this is a topic where consensus has not been reached by the scientific community, and makes it emphatically not one of those texts where science is represented as "established, permanent, incontrovertible fact" (Lemke 1990:137).

4.2.2.2 Nominalisation and embedding in Duff

The following analysis indicates that both nominalisation and embedding contribute to the highly 'written' nature of Duff in that both contribute to place the burden of meaning of the text in the nominal group. In congruence with the use of material and verbal processes to express conceptual rather than physical meanings, nominalisation functions to foreground ideas and remove people from the account. As discussed above under transitivity (section 4.2.1), embedding functions to increase the abstract nature of the text.

Nominalisation in Duff

The following 30 different nominalisations are found in this 540 word extract:

[1]*Use*, [1]*interpretation*, [1]*evolution*, [3]*interpretation*, [3]*extinction*, [3]*assemblages*, [3]*extinction*, [4]*emergence*, [4]*evolution*, [4]*change*, [4]*catastrophism*, [4]*gradualism*, [5a]*forms*, [5b]*changes*, [5b]*competition*, [6b]*preservation*, [7a]*intensity*, [7b]*extinctions*, [7b]*increases*, [7b]*forms*, [7b]*radiations*, [8]*decline*, [8]*radiation*, [8]*decimation*, [9]*support*, [9]*catastrophism*, [9]*evolution*, [10b]*forms*, [11]*attention*, [12]*sedimentation*, [12]*examination*, [12]*peculiarities*, [13]*enrichment*, [14]*significance*, [14]*anomaly*, [16b]*volcanism*, [16b]*outpourings*, [17]*reality* [17]*catastrophism*, [17]*extinctions*, [19]*extinctions*, [19]*survival*

This makes Duff a highly nominalised text, even more highly nominalised than Raup and Sepkoski. Table 4.2.6 compares the amount of nominalisation in Duff to the amount in Raup and Sepkoski, McGhee and Trefil and Hazen:

Table 4.2.6: Nominalisation in Duff compared to other textbooks and research article

	Duff	McGhee	Trefil and Hazen	Raup and Sepkoski
Different nominalisations per 1000 words	56	45	7	43

Nominalisation enables the author to avoid mentioning an agent, while at the same time allowing research, ideas and abstractions to be actors in the passage. The following uses (in bold face) of nominalisation side-step the fact that some agent – usually people – is doing the using, interpreting, assempling, supporting, attending, examining:

[1]*The stratigraphic* ***use*** *of fossils ... may proceed*

[3]*Perhaps the simplest* ***interpretation*** *of the extinction of faunal and floral assemblages, was that of* ***extinction*** *by catastrophe*

[6a]*Wherever there were gaps in the fossil record ...* [6b]*it was maintained that this was due either to lack of* ***preservation*** *..*

[9]*Linked with modern* ***support*** *for catastrophism...*

[11]*Much* ***attention*** *has been paid to the Cretaceous/Tertiary (K/T) boundary.*

[12]***examination*** *of clays has shown some chemical and mineralogical* ***peculiarities***.

As Halliday (1993) points out such nominalisation allows the argument of the text to progress It also compresses a lot of information into a clause. (For example clause 3 without nominalisation would become far more than one clause, would be something like: "If people look at fossils of past fauna and flora, they can assemble these fossils into lists indicating when these fauna and flora existed. One simple way of interpreting these lists is to suggest that these fauna and flora became extinct because of a catastrophe".)

The following instances indicate how ideas have become actors in the text. In clause 4 the idea/abstraction of evolution becomes an actor. In clause 7 research, rather than researchers, becomes an actor. Clause 12, 13 and 14 make an attribute – e.g. peculiar – into a thing in its own right - peculiarity.

[4]*with the **emergence** of evolution as a dominating idea*
[7a]*Palaeontological **researches** have proceeded with ever-increasing intensity*
[12]***examination** of clays has shown some chemical and mineralogical **peculiarities**.*
[13]*In particular the boundary is marked by an **enrichment** in the element, iridium.*
[14]*The **significance** of this anomaly lies in the fact that this element is more abundant in planetismals.*

McGhee, the textbook for advanced students that I analysed, is very like Duff in that the major function of nominalisation in McGhee is to allow ideas, theories and attributes to become things. By contrast, Trefil and Hazen, the textbook for non-science students contained only four different nominalisations in a text of 540 words, three of these being very carefully explained. This is comparable to the number in the texts for children, and lower than the number in the three popular texts. So the authors of Trefil and Hazen regard their readers as unlikely to tolerate even the number of nominalisations acceptable to the (educated) readers of newspapers and news-magazines. This indicates that the extent of nominalisation in Duff and McGhee may well be a function of the extent to which the writers regard the readers as acculturated into the discourse of geology.

This analysis of nominalisation in Duff supports my analysis of transitivity in the sense that both reveal an abstract impersonal text in which people and things are suppressed and ideas, research and abstractions are the true actors.

Embedding in Duff

One of the features that makes Duff a highly 'written' text is the large amount of embedding. The sentences are very long, but there are fairly few clauses. It has more words per clause than any of the texts analysed, having slightly more than the Scientific American text. There are a large number, too, of what Thompson (1996:141) calls 'heavy' themes: those giving a large amount of information. It is embedding that is used to make these themes heavy.

As discussed above in section 4.2.1.2, the question of evolution is not addressed in ranking clauses but is rather packaged in embedded clauses and phrases and adjuncts. The claim is usually made that packaging information in embedded clauses makes it less negotiable. In this case it also makes the text much more abstract, in that the skeleton of the argument concerning two possible theories (gradualism and catastrophism) is present in the ranking clauses but that the subtleties of the argument concerning the nature of evolution is packaged within the nominal group as embedding and adjuncts.

There are 15 instances of embedding in Duff although there are only 19 clause complexes. Seven of the instances of embedding are clauses. As Table 4.2.7 indicates, most embedded material goes into thematic position in the clause, reinforcing Martin's (1993:246) contention that through embedding, processes have a larger role to play in themes and thus in method of development. The exception is embedded important new material, which is more likely to be found in the rheme.

Table 4.2.7 Function of embedded clauses in Duff

Function of embedded phrase or clause	In theme	In rheme
Summarizes Given material	4	
Aside/detail – unimportant new material	3	1
Elaborates – fairly important new material	2	1
Important new information – clause wouldn't make sense without it	1	3

In Raup and Sepkoski, the research article considered in section 4.1, embedding played the role of adding highly specific but relatively peripheral information on the one hand and of packaging important propositions into fact clauses on which the authors could comment. In contrast, in Duff, embedding plays the role of increasing the level of abstraction by siting discussion about evolution within embedded clauses. Author commentary on the credibility of these ideas is once again sited in ranking clauses (e.g. [3]*Perhaps the simplest interpretation;* [6b]*it was maintained that*). In McGhee a similar situation in terms of abstraction is found in that real world meanings (such as [8]*an asteroid did impact the earth*) are packaged into the embedded clauses leaving meanings concerning research, meanings concerning ideas, and evaluative commentary on embedded meanings to be realised in the ranking clauses. Once again this increases the level of abstraction in the text

4.2.2.3 Passivisation in Duff

In what follows I report on my examination of the use of the passive voice in the Duff extract. As readers will see, extensive use of the passive is one of the features of the text that result in a very impersonal text. Many processes (13 out of a total of 29 finite processes) in this extract are passive. In many places this permits the author to avoid explicitly saying who the sayer/actor is but in other places sayer/actor is still included. Use of the passive to avoid mention of the sayer is understandable, because the author of the text, like most textbook authors, has no wish to attribute all ideas to individuals. In Duff where the processes have no sayer, sensor or actor, the implied sayer, sensor or actor is geologists or palaeontologists. In the remaining case the implied actor is palaeontological research. Instances of the passive are in bold face in the examples below:

[4]*catastrophism* ***was challenged*** *by notions of gradualism.*
[5a]*Diverse forms* ***were thought*** [5b]*to arise from ancestral stocks.*
[6]*Wherever there were gaps in the fossil record .. it* ***was maintained*** *that this was ..*
[8]*Thus the major boundaries in the stratigraphic column ...* ***have been reinforced.***
[11]*Much attention* ***has been paid*** *to the Cretaceous/Tertiary (K/T) boundary.*
[15a]*So it* ***is maintained*** *that the Earth was hit by an extra-terrestrial body.*
[16a]*The topic* ***is still hotly debated;*** [16b]*it* ***is pointed out*** *that ...*

So, interestingly, if this short extract is anything to go by, textbooks are science with the individual scientists and most of the details of their research removed. Their results/ideas only are retained. Textbooks are attempts at descriptions of reality, 'the facts'. Gerot (1995:99) maintains that impersonal projection "is a form of interpersonal grammatical metaphor, of modality, one which allows the writer to claim objectivity for something that in fact is a matter of opinion". However, I do not believe that we can claim this about this extract from Duff because the topic of the extract is controversy. The mental and verbal processes actually confirm this. They stress the fact that these are opinions rather than trying to claim objective certainty.

There is also extensive use of passive processes (in bold below) with the inclusion of the actor (underlined). In clause 3, 13 and 15a the passive construction appears to function to place Given (known) material in thematic position (i.e. its natural position). In clause 10a and 10b an event mentioned in the goal (e.g. [10a]*long periods of little change*) precedes the event in the actor (e.g. [10a]*mass extinctions*) and could thus be argued to naturally come first. In clause 19 the writer appears to want to foreground the goal ([19]*the case for mass extinctions by catastrophe involving not the survival of the fittest but the survival of the* *luckiest*) in thematic position as in the seven cases above where the actor is omitted. Nevertheless the writer wishes to provide the name of the book and its author for the information of the undergraduate reader. Interestingly, most of these processes (actor/ sayer supplied) are material processes and describe happenings in the physical world. This is in contrast to most processes in the group above (with the sayer omitted) which are largely mental or verbal.

[3]*Perhaps the simplest interpretation of the extinction of faunal and floral assemblages, ... was that of extinction by catastrophe*. On the other hand, [4]*with the emergence of evolution as a dominating idea in biological change, catastrophism* ***was challenged*** *by notions of gradualism*.

In this extract catastrophism is Given and thus naturally falls into thematic position. It is gradualism that the writer wants to emphasise here. The situation is similar in clause 13 and 15a:

[13]*In particular the boundary* ***is marked*** *by an enrichment in the element, iridium*.
[15a]*that the Earth* ***was hit*** *by an extra-terrestrial body*.
[10a]*Long periods of little change in widespread forms* ***are ended*** *by mass extinctions*.
[10b]*and the vacated ecological niches* ***are then taken over*** *by forms which have diversified in relatively isolated areas.*

Clauses 10a and 10b are passive to place an event that precedes another event first. '*The long period of little change*' happens first, then comes '*mass extinction*'. Similarly, '*ecological niches*' are vacated first, and then they are taken over by '*other forms*...' Also, it is the [10a]*mass extinctions* and [10b]*the forms which have diversified in ... isolated areas* that the writer wants to emphasise, so they come in New position in the clause.

[19]*On the other hand the case for mass extinctions ...* ***has been developed*** *recently in a stimulating and provocative account Wonderful Life by the American writer S.J. Gould.*
This example is, I would maintain, more like those in clauses 4, 5a, 6, 8, 11, 15a and 16a where the sayer has been omitted. Gould's ideas are more important than he is and so go in thematic position, but his name and book are included by way of recommending to the undergraduate readers a book which may be interesting, useful and accessible to them

The extent of passivisation in this text and the relative lack of passivisation in the other genres such as popular journal articles, children's texts and even research articles makes me wonder if the common idea that science writing is full of passives may not be based largely on textbooks. Use of the passive is as extensive in McGhee (the textbook for advanced students) as it is in Duff, and serves the same purpose of avoiding mention of individuals while foregrounding their ideas and findings. Trefil and Hazen, the textbook for non-science students, also foregrounds ideas and findings rather than individuals but it does not employ the passive extensively to achieve this. Instead it uses the approach adopted by books for children: that of using the generic [12]*geologists* and [17a, 25]*scientists*, which also effectively backgrounds individuals and makes the focus the ideas and discoveries that this generic group has made.

In summary, the extensive passivisation in Duff, as in McGhee, serves not to obscure agency, but to foreground what is important in the context of textbooks: the facts/findings/ideas of scientists/researchers, who themselves are of marginal importance. Writers of textbooks, are summarising findings in the field rather than primarily presenting their own ideas or findings. It is also clear that passivisation is not used in Duff to obscure the fact of controversy, as controversy is stressed in numerous mental and verbal processes such as [16a]*debated*, [4]*challenged* and [15a]*maintained*.

Table 4.2.8 Conjunctive relations in Duff

Internal conjunctive relations: rhetorical structure	clause	External: real world conjunctive relations	
	1		
	2	Addition: adversative	But
	3		
	4	Addition: adversative	On the other hand
	5b		
	5c		
	6a		
	6b		
	7a		
	7b	Addition: adversative	but
	8	causal	Thus
	9		
	10a		
	10b	extension: addition	and
	11		
	12		
	13	particularising	In particular
	14		
	15a	causal	So
	15b		
	16a		
	16b		
	17		
	18b		
	19	Addition: adversative	On the other hand

4.2.2.4 Conjunctive relations in Duff

As Table 4.2.8 shows, causal relations in Duff are traced conjunctively in two instances, but for the most part appear to be achieved through identifying processes within the extremely long clauses, rather than between clauses. As might be expected in this text, which functions to distinguish between different ideas, there are many adversative conjunctions. This use of adversative conjunctions to signal the differing viewpoints and theories coincides with my analysis of transitivity and theme in that it indicates a text in which ideas that are being advanced by different voices are foregrounded.

4.2.2.5 Summary and overview of Mode in Duff

My analysis of mode in this text reveals an apparent contradiction. On the one hand the author combines the use of marked embedded 'heavy' themes, adjuncts as theme and adversative conjunctions to indicate to the reader that there are opposing present and past voices on the topic and that no consensus has been reached. This indicates that for this audience (beginning Geologists), and on this topic, Lemke's claim (1990.137) that science is represented as "established, permanent, incontrovertible fact" does not hold. On the other hand the author conceals the individuals behind the opposing voices, by using a high level of nominalisation and passivisation. This I interpret as indicating that in textbooks, the facts are far more important than the individuals who discovered them (just as in research the research community is far more important than the individual researcher, as Myers (1989) shows).

4.2.3 Tenor in Duff

Tenor refers to the roles of the reader and writer of a text and interaction between them. This text is written by an expert, who is providing knowledge for unknown 1st year students. Thus we expect a fairly high degree of distance between the reader and writer, and we could expect evidence of unequal status between the reader and writer. In this section, therefore, I consider the categories of contact, affect and status, hedging, and evaluation.

4.2.3.1 Contact, affect and status in Duff

In this section, as I do in 4.1.3.1, I consider contact, affect and status in Duff, three categories that Gerot (1995:104) uses to illuminate the interpersonal metafunction.

Contact in Duff

Contact refers to a writer's solidarity with his/her readers (Gerot 1995:104). Because of the high level of passivisation, nominalisation and embedding, the large number of technical terms, and because, as discussed above, the material processes deal for the most part with ideas, the text is extremely formal. There is no colloquialism or jokiness, which are some of the usual ways for a writer to show solidarity with a reader. On the other hand, we could argue that the writer does show solidarity with the reader by initiating the reader into the debate on the topic over '[2]*the last two centuries*'. In doing this, the writer recognises the reader as a serious student of geology. Also it could be argued that the writer shows solidarity with a certain group of his readers: those who are able to read and benefit from this lexically very dense, abstract text – that is those who are already well on their way to becoming 'members of the Discourse' of geology.

The readers of Duff are first year students of geology and thus need to be referred to [7b]'*the stratigraphic column (see Table 7.1)*'. By contrast, the more advanced readers of McGhee are assumed to be familiar with the stratigraphic column, and the text refers for example to [8]'*the end of the Maastrichtian Age in the Late Cretaceous*'. At the other end of the spectrum of university textbooks Trefil and Hazen (the authors of the textbook for non-science students) position the reader as "not a geologist and not a scientist". They do this in such phrases as: [17a] '*Most scientists today accept*', and [25] '*Scientists continue to debate*'.

In some texts in this study, such as the books for children, illustrations are used to show solidarity with readers. The extract from Duff, refers to '*Table 7.1*' (see appendix page 10 and 11). This is the '*classification of geological Eras and Periods*', and appears on the previous page. As we might expect from the text, the geological column is more abstract than the similar geological columns in Trefil and Hazen (appendix page 21) and <u>Time</u> (appendix page 30). Firstly the sequence is not shown to scale (one column indicates how many million years ago a certain Period was). Secondly, there are no pictures or arrows indicating the duration of various phenomena as in Trefil and Hazen. It also gives more information such as breaking down the eras into periods, the derivation of names etc. There is no joking or use of dimension as in <u>Time</u>.

Affect in Duff

Affect refers to 'positive or negative attitude of the writers to the readers and what they are talking about' (Gerot 1995:104). There is no evidence in Duff of personal feelings of the writer for the reader. The text is extremely impersonal, giving (within the context of science and western culture) the impression of a highly objective text, which in turn adds to the truth value of what is said in the text. The only deviation from the impersonality and lack of attitudinal lexis is the positive evaluation – [19]*stimulating and provocative* - of a popular account of the matter, indicating perhaps that this is the writer's assessment of the subject matter in general. Reader and writer are, to varying extents, identified as geologists, so there is no distance between them and scientists as a group. Scientists are regarded as developing theories, gathering quantitative data and making measurements in a sincere and objective attempt to approximate the facts, which however are not completely clear yet.

Status in Duff

Status refers to how the writer includes the reader (Gerot 1995:104). As noted, the text is severely impersonal, and neither the writer nor the reader is explicitly included in the text. '[17]*Some palaeontologists*', '[3]*French geologists*' and '[19]*the American writer S.J. Gould*' are the only human participants of the text. As I point out below there are no reader-oriented hedges, so the writer does not show any deference to the reader. The relative statuses are writer as expert and reader as student or initiate into the field. However the writer does include the reader in the text and in the discourse community by recommending a popular source in enthusiastic terms.

4.2.3.2 Hedging in Duff

In this section I report on the hedging in Duff. Hedges express tentativeness and can either be used to show a writer's lack of commitment to a proposition (p) or a desire not to express commitment (Hyland 1996a: 478).

Duff has fewer hedges than any of the other texts in the study. The hedges in the text are of two types: reliability hedges (indicate writer confidence) and writer-oriented hedges (limit writer commitment). Although the text is written in an abstract and detached way, the low number of hedges mean that this is not achieved through hedging as the writer gives the impression of being very assured of what he is saying.

Table 4.2.9 Hedging in Duff (following Hyland 1996c)

	Hedges	Reason for the hedge
3	**Perhaps** the simplest interpretation of the extinction of faunal and floral assemblages	Reliability hedge – assessment of the reliability of p (proposition). Writer has some doubt that this is the simplest?
5a	Diverse forms **were thought** to arise from ancestral stocks ...	Writer-oriented – writer hedges commitment to p
6a	...**it was maintained** that this was due to lack of preservation...	Writer-oriented – writer hedges commitment to p
15a	So **it is maintained** that the Earth was hit by an extraterrestial body	Writer-oriented – writer hedges commitment to p
16b	[16b]**it is pointed out** that excessive volcanism ... would have effects...	Writer-oriented – writer hedges commitment to p
16b	volcanism ... **would have** climatic effects to which some organisms **could not adapt.**	Reliability hedge – writer communicates that there is some doubt about p
16b	excessive volcanism, **perhaps** associated with the outpourings of the lavas of the Deccan Traps . .	Reliability hedge– for the writer there is doubt about p – maybe it was associated with the Deccan traps, maybe not
17	Some palaeontologists ...**would resist** catastrophism	writer-oriented hedge
18b	**many would maintain** that these reptiles had been gradually dying out for some time ...	writer-oriented hedge

Note that in my opinion the following instance of modality (bold-faced) is not a hedge:

> '[1]*The stratigraphic use of fossils for purposes of correlating rocks from one area to another* ***may proceed*** *without any theoretical interpretation of the nature of evolution.*'

It does express possibility, but it is not possibility in the sense that there is any chance at all that p will/does not happen. In this case *may* could be replaced with *can* as it is potential rather than possibility that is being indicated. There is no indication that this is the speaker's opinion/attitude. I look on this statement as being what Hyland (1996,450) calls a categorical assertion where the speaker is committed to p and its truth value.

Another example of what at first looked like a hedge but in fact is not a hedge is:

> '[9]*Linked with modern support for catastrophism is a process which* ***has been called*** *punctuated evolution.*'

Rather than a writer-oriented hedge, what the writer is actually doing here is supplying the name for the phenomenon.

Although I finally classified the following mental and verbal processes as writer-oriented hedges (writer hedges commitment to p) I did have some doubt about them:

> [5a]*Diverse forms* ***were thought*** [5b]*to arise from ancestral stocks by gradual changes imposed by physical conditions and biological competition;* [5c]*unsuccessful forms died out over variable periods of time.* [6a]*Wherever there were gaps in the fossil record with sudden changes in fossil content,* [6b]***it was maintained*** *that this was due either to lack of preservation or inadequate collecting or both.*
> [17]*Some palaeontologists ...* ***would resist*** *catastrophism and instantaneous extinctions.*
> [18a]*With regard to the dinosaurs and the K/T boundary* ***many would maintain*** *that these reptiles had been gradually dying out for some time ...*

The problem is that the writer is recounting the history of thought on the topic. I do not think the writer agrees with the content of clause 5b, 17 or 18a or the reason provided in clause 6b. But whether he is hedging commitment to these propositions is not entirely clear. It could be argued that he is making it quite clear that those who thought or maintained these things were wrong.

Table 4.2.10 Kinds of hedges in Duff compared to other textbooks and research article

Hedges	Duff	Trefil & Hazen	McGhee	Raup and Sepkoski
Reader-oriented hedges				**13 (59%)**
Writer-oriented hedges	**6 (66%)**	**6 (25%)**	**20 (40%)**	4 (18%)
Attribute hedges		9 (38%)	2 4%	
Reliability hedges	**3 (33%)**	**9 (38%)**	**28 (56%)**	4 (18%)
Reliability/ reader-oriented				1
total	9	24	50	22

Table 4.2.10 shows that the three textbooks are similar in hedging content (whether as reliability or attribute hedges) indicating a desire to share with the reader the writer's confidence in the truth of a proposition. The textbooks also hedge writer commitment to what is being said, attributing it to geologists, scientists or in the case of McGhee, specified researchers. The kind of hedge which is missing, but is prominent in the research article by Raup and Sepkoski, is reader-oriented hedges (which hedge assertiveness, functioning to get acceptance of claims which threaten the face of other researchers (Myers 1989)). This indicates a major difference at the interpersonal level between textbooks and research articles. Writers of research articles are obliged to show deference to their readers, who represent the powerful research community. Writers of textbooks direct their writing at readers who are less powerful than themselves and who are newcomers to the field In summarising the accepted facts of the field, we could view the writer of a textbook as speaking for and representing the discourse community (the same group who are the readers of the research article). The ideas presented in a textbook

are for the most part not the ideas of the writer. They are ideas that have been given the stamp of fact by the discourse community. In the textbook the fact/idea is primary, the individual, whether reader, writer, or researcher who first proposed the fact, is secondary. This analysis of hedging has pointed to an important difference between the relative statuses of reader and writer in research article and textbook.

4.2.3.3 Evaluation in Duff

Evaluation is a category that includes all meaning that functions to express the writer's opinion and value system, and to construct and maintain relations between the writer and reader (Thompson and Hunston, 2000:6). I begin my account in Table 4.2.11 by categorising evaluation in each clause in the way suggested by Hunston (1993, 1994).

Table 4.2.11 indicates that Duff sets up three sets of oppositions. The first is between two hypotheses: catastrophism and gradualism; the second between positive and negative evaluations of the catastrophism hypothesis; and the third between two alternative variations on catastrophism: impact and volcanism.

In clauses 1-8 the two hypotheses are introduced. In terms of Certainty they are largely assessed as possible. In terms of Value, the catastrophism hypothesis (clause 3) is assessed as useful (having explicatory power). The gradualism hypothesis (clause 5-8) is negatively assessed in terms of accuracy (lack of fit to data), usefulness (explicatory power) and applicability (lack of fit to a range of data). Thus in these four clauses (5-8) the writer negatively evaluates and more or less rejects the gradualism hypothesis. The rest of the text concentrates on evaluating the catastrophism hypothesis Here we see a sequential positive-negative-positive evaluation, which is much more pronounced in the popular texts. Clauses 9-11 outline the catastrophism hypothesis. All clauses in this section are evaluated as certain. Clauses 12-14 are also evaluated as certain. They positively evaluate the catastrophism hypothesis as accurate (with a close fit to the data). Clauses 15-16 consider two variations on the catastrophism hypothesis: impact by an extraterrestrial body, and volcanism. These variations are evaluated as possible in terms of Certainty and are useful (having explicatory power) in terms of Value. Unnamed geologists are the source of almost all information in this text. Clauses 17-18 then move to a negative evaluation of the catastrophism hypothesis on the part of 'some palaeontologists' and 'many', who, in terms of Value, evaluate the catastrophism hypothesis as being not accurate (fit to data).

Table 4.2.11 Evaluation in Duff

Status					Value
Clause	Activity	Source	Modification	Certainty	value
1	interpretation	writer	may proceed	possible	
2	interpretation	writer		certain	
3	hypothesis catastrophism	writer, 19th century French geologists	perhaps	possible	**catastrophism Hypothesis** + useful
4	interpretation	writer		certain	
5a	project				
5b	hypothesis gradualism	unnamed geologists	were thought	possible	**Hypoth gradualism**
5c	hypothesis gradualism	unnamed geologists	were thought	possible	
6a	interpretation				
6b	hypothesis	unnamed geologists	was maintained	possible	- accuracy
7a	event	Unspecified research articles		certain	
7b	interpretation	writer		certain	- useful
8	interpretation	writer		certain	- applicability
9	Hypoth catastrophism	Modern support unspecified geologists		certain	**Hypoth catastrophism**
10a	Hypoth catastrophism	Modern support unspecified geologists		certain	
10b	Hypoth catastrophism	Modern support unspecified geologists		certain	
11	attention	unspecified geologists		certain	
12	result	unspecified geologists		certain	+ accuracy
13	result	unspecified geologists		certain	
14	Interpretation/ result	writer/ unspecified geologists		certain	
15a	hypothesis	unspecified geologists	it is maintained	possible	**Hypothesis catastrophism extraterrestrial**
15b	interpretation	unspecified geologists	it is maintained	possible	+ useful
16a	interpretation	unspecified geologists	still hotly debated	possible	
16b	Hypothesis volcanism	unspecified geologists	it is pointed out, perhaps would have	possible	**Hypothesis catastrophism volcanism** + useful
17	interpretation	Some palaeontologists	would resist	possible	
18a	project				
18b	interpretation	many	would maintain	possible	- accuracy
19	hypothesis	SJ Gould	provocative account	possible	+ useful + stimulating + provocative

Finally catastrophism is positively evaluated as useful (having explicatory power) in the final clause. Interestingly, a popular account is also positively evaluated as "[19]stimulating and provocative" in this final clause. This is similar to the value 'interesting' (mentioned five times in McGhee and once in Trefil and Hazen). Trefil and Hazen also share the values of '[6]best known' with the popular science texts. Together with Trefil and Hazen's reference to the (in scientific terms) celebrity status of Luis Alvarez as a Nobel-prize winner, this makes Trefil and Hazen closest of the three textbooks to a popular science text.

The writer attempts to give a balanced, objective view of the matter. In my opinion, he comes closer to achieving this than any of the other texts. Raup and Sepkoski, while forced to write in an objective style, are obviously not impartial: they have much invested in having their periodic catastrophe hypothesis (for which they provide evidence) accepted by the research community, and they would also like support for their extraterrestrial hypothesis (because it seems reasonable to them). The writer of the Scientific American article also writes in an objective style to the extent that s/he presents both sides of an argument. However s/he finds one side of the argument more convincing and is prepared to assert that it is more convincing in the final paragraph. The author of the Mail and Guardian text makes no attempt to appear objective. The author of the Time article appears objective because there is little attempt to reconcile the two sides of the argument. Material on each side of the argument is merely juxtaposed in adjacent paragraphs. Closest to the textbook in objectivity are the four children's texts.

In summary this section shows that the author evaluates the gradualism hypothesis negatively in terms of accuracy, explicatory power and fit to data. Catastrophism fares better with a negative evaluation on the part of some palaeontologists sandwiched between two sections positively evaluating the hypothesis. The source of most clauses is the writer or unspecified research articles and thus apparently the writer. Thus evaluation is fairly overt in this text, with the writer prepared to go on record with his evaluations. I have argued that paradoxically this makes the writer appear more objective than if evaluations were avoided (as in the research article) or if evaluations are made through the voices of participants in the text as in the popular articles.

4.2.3.4 Summary and overview of Tenor in Duff

The analysis of Tenor in the Duff text indicates a formal, impersonal text giving the impression (within the value systems of science and western culture) of objectivity and resulting high truth value. Although the text is written in an abstract and detached way, the low number of hedges mean that this is not achieved through hedging (which indicates through modality the exact extent of writer certainty). This text has less hedging than any of the other texts in the study, giving the impression that the writer is sure of what he is saying. This confidence on the part of the writer is supported by the fact that evaluation in the text is fairly overt and on record. There is no mention of either the reader or writer in the text, although the writer does 'recognise' the reader to the extent that he treats the reader as an initiate into the field by outlining the important developments in the field over the last couple of centuries. The unequal nature of the expert/student relationship is indicated in the lack of solidarity politeness (reader-oriented hedges) towards the reader. Further than this, in the section on hedging I suggested that writers of textbooks have power because they are summarising facts that have been endorsed by the science discourse community, of which they are in a sense the voice.

4.2.4 Summary and overview of Register in Duff and other textbooks and comparison with research articles

The textbooks and research article in this study are similar in terms of register (context of situation), but different in terms of genre (context of culture). As mentioned in chapter 2, Halliday (1993:56) describes the scientific register as recognisable because of the effect of "clusters of features". Amongst these are nominalization of verbs and adjectives, extended nominal groups, a high proportion of relational processes, technical terms, tentative language, causal and reasoning verbs, and impersonal language and passivization. These features are indeed found in the textbooks and research article in this study, and there is a great deal of similarity between the two genres when these features are compared. Both research article and textbooks reflect a high level of nominalisation and of technical language. The exception is the textbook for non-science students, where the proportion of nominalisations is as low as it is in the texts for children. This is presumably a deliberate move on the part of the writers of this textbook to make it as accessible as possible to its non-specialist readers. It is interesting to note that in the other two textbooks (for first year and more senior geology students), the level of nominalisation and technical language is as high as in the research article. The writers of these textbooks are addressing readers who are possible future Geologists/colleagues, and they are expected to be more integrated into the discipline. They are expected to be closer to being 'members of the Discourse' (Gee 1990), those who are able to speak/write/read, act and think in the 'culturally' appropriate manner.

In both the research article and the textbooks in the study, embedded clauses are employed to extend the nominal group. All four texts employ clauses embedded in the nominal group to increase the level of specificity of what is said, and to package central propositions into facts. These are often imported from other texts and are often subjected to evaluative commentary sited in the ranking clause. In two of the textbooks, Duff and McGhee, this embedded material serves to increase the abstraction of the texts. This is because information on a particular topic (evolution in Duff and real world information in McGhee) is sited in embedded clauses so the text functions on more than one level.

In both the research article and the textbooks in the study, relational clauses are twice as common as material clauses. Attributive processes attribute characteristics while of the identifying processes, most show relations of equivalence, with cause also being realised through identifying processes rather than through the more congruent choice of conjunctions. The exception to this high level of use of relational processes compared to material processes is the first year textbook, Duff. Curiously, in Duff, almost all material processes express meanings to do with abstract ideas, which would congruently be expressed in relational processes. Duff thus appears to treat ideas almost as if they are things.

Another area of similarity between these two genres is the removal of human participants and wide use of the passive voice. The ultimate function of this in both genres is to establish that what is being said is objective, but achievement of this aim is slightly different in the two genres. In the research article removal of human participants and use of the passive is more complex than in the textbooks. As discussed in chapter 2, establishment of information as factual and objective involves removal of time, place and the people from whom the information originated. The writers of the research article remove themselves as agents, and thus use the passive, to make their knowledge claims appear as objective as possible. At times they remove other researchers for reasons of politeness: to avoid disagreeing with them. For example:

[7a]*It has been generally assumed that ...* [8]*Following this view...*

At other times they imply that ideas they agree with are widely accepted by not attributing these ideas:

[9]*There is increasing evidence, however, that many extinctions are actually short-lived events of special stress...*

By contrast, the textbooks in the study appear to remove human participants and use the passive for the reason that facts are more important than the people that first thought of them are. One of the textbooks (McGhee) includes those who proposed the information as citations; that is, human participants are present but in a very impersonal way. They are not the agents of the research, or the subject of the clauses in which they appear. In this case they seem to serve the function of allowing the projected senior student readers to refer to the articles. The other two textbooks have generic rather than specific scientists as human participants, as is more common in textbooks as a genre. Once again this is a function of facts being more important than the people that first thought of them are.

The major differences between the textbooks and research article are in terms of genre (considered in the sense prominent in the Australian school), in terms of relationship between reader and writer, and, related to this, in terms of persuasive intent. I give attention to these in the next two sections.

4.2.5 Genre in Duff and other textbooks

My account of genre in chapter 4.1 notes that research articles contain discussion, recount and exposition, but that these are likely to be associated with particular sections. By contrast, textbooks are likely to contain a good deal of information report, explanation and procedure, and these are not associated with particular sections but rather are used according to the needs of the writer and the subject under discussion.

Duff is a widely-used textbook for first year students. Originally written by Holmes (in 1944), it has been revised four times, in this edition by Duff, originally one of Holmes's students. Because of the newness of this information we can assume this section to be new. The extract from Duff considered in this research contains elements of both information report and discussion. The first paragraph (clause 1-6) is set up as a discussion, while the second and third paragraphs are more like an information report. Clause 1 links the extract to the previous topic in the chapter. Clauses 2-6 are apparently a discussion (Butt et al 1999:20) with clause 2 a statement that there is a debate. Clause 3 states the catastrophism side of the argument, and clauses 4-6 the gradualism side of the argument. The second and third paragraphs have some similarity with Butt et al's (1999:19) outline of the structural features of an information report. They present evidence in support of the first argument (catastrophism) and could be said to be a 'sequence of related statements grouped in topic areas' (Butt et al 1999:19). Paragraph 2 presents evidence from the stratigraphic column, and paragraph 3 presents mineral evidence linked to two theories of what caused the mineral evidence (extraterrestrial body and volcanism.) No attempt is made to persuade the reader. Evidence is provided to support catastrophism only, and the reader is left to conclude that this is the correct interpretation of the facts.

McGhee is in the form of an information report. The first paragraph (clause 2-7) raises the possibility of mass extinction caused by an extraterrestrial body, and loosely fills Butt et al's (1999:19) slot, 'general opening statement or classification'. The other nine paragraphs support this with a 'sequence of related statements grouped in topic areas' (Butt et al 1999:19). Paragraph 2 (clause 8-12) presents chemical and paragraph 3 (clause 13-15) mineralogical evidence. Paragraphs 4 (clause 16-19) and 5 (clause 20-23) propose climatic effects consequent on impact by an extraterrestrial body. Paragraphs 6 (clause 24-29), 7 (clause 30-31) and 8 (clause 32-34) suggest variations on interpretation of the data. Paragraph 9 (clause 35-41) relates the data to the stratigraphic record, while the final paragraph (clause 42-48) suggest other intra-solar mechanisms for mass extinction.

As with Duff, no attempt is made to persuade the reader of any of the information. The readers are given the facts and left to draw their own conclusions. An exception to this directness is two instances where readers are more obliquely told what to think. The first instance is the exclamation mark in clause 31b, which indicates to the reader that the writer finds this argument questionable:

> [31b]*an alternative impact hypothesis has been proposed (Hut et al 1987) in which a series of smaller impacts, ... is argued to have produced the sequential extinctions!*

The second instance is the apparent hint in clause 7 that the idea that 'all mass extinctions are triggered by impacts' is unsupported.

> [7]*others have gone to the extreme of maintaining that all mass extinctions are triggered by impacts, and that these impacts occur with clock-like regularity.*

This hint is however revisited with greater definiteness in clause 35, where readers are given clear direction by the writer that most mass extinctions were not caused by impacts:

> [35]*To date a strong case cannot be made for large impacts during crisis intervals other than the Late Cretaceous and Late Eocene events ...*

Trefil and Hazen is once again an information report. The first paragraph (clauses 2-5) corresponds to Butt et al's (1999:19) 'general opening statement or classification' in that it raises the idea of mass extinction and distinguishes it from the 'normal' gradual rate of extinction. The second, third and fourth paragraphs correspond to Butt et al's 'sequence of related statements. Paragraph 2 (clause 6-12) mentions various different mass extinctions. Paragraphs 3 (clause 13-16) and 4 (clause 17-20) provide evidence of various type for extra-terrestrial impact. Finally, paragraph 5 (clause 21-27) corresponds to Butt et al's 'concluding statement' in that it suggests implications of what has been said for the rate of evolution (gradual versus catastrophic).

As a genre, textbooks contain a summary of the information that has been accepted by the research community as fact. This information is structured in a range of genres (in the sense used in the Australian school) including in this selection information report, explanation, procedure. Besides these, other factual genres are likely to be included in textbooks: discussion, exposition, recount, and at times, narrative.

4.2.6 Ideology in textbooks

In general university textbooks are aimed at an undergraduate audience, who want a synthesis of all current facts, theories etc. The individual researchers who first thought of these facts and theories are of less importance than the progress of the field as a whole. Myers (1989:4) has characterised the science discourse community as one in which individual researchers are very much less important than the community as a whole. Similarly, I would argue, individual researchers are of less importance than their ideas, which ideally build on and seamlessly mesh with the ideas of others. The assumption appears to be that the truth/the reality/Nature is 'out there', and the work of a scientist is just to find out about it and describe it. Thus in textbooks, the role of only really key researchers – usually from the nineteenth century - is mentioned: individuals of the stature of Darwin, Faraday, Marie Curie etc. Less famous nineteenth century scientists and current/modern researchers are generally not mentioned by name.

Many features of Duff and other textbooks combine to create the impression of objectivity and thus high truth-value. Firstly there is the impersonality of the text, which is achieved through the dearth of human participants, those present being mainly generic. To achieve this the writer uses passivisation, and nominalisation. He achieves a high level of detachment through this impersonality and through use of agentless mental and verbal processes. This impersonality is a feature of textbooks and an indication that facts are more important in textbooks than the people who discovered them. In spite of the facelessness of the human participants in the text, the writer is at pains to indicate to the reader, through thematic development and use of conjunction, that there are opposing voices on the topic and that this is not an area where consensus has been reached. This is not an area of science that is represented as "established permanent fact" (Lemke 1990:137). The formal and abstract table that is the only illustration for this extract of the text also has high objectivity/truth value.

The abstract nature of Duff also adds to the impression of objectivity In this text ideas rather than people are the main actors. Most processes – material, relational and verbal and mental – express meanings to do with ideas rather than with happenings or things. Part of the argument in this text – that concerning the nature of evolution – is sited entirely in embedded clauses, making this information less negotiable than information in ranking clauses. Even the features that are in apparent contradiction of this objectivity – the dearth of hedging and the overt evaluation – give the impression that the writer is giving his true opinion and making no effort to convince/persuade us.

Thus readers of textbooks are not persuaded by the writer, who has a 'take or leave it: these are the facts' approach. By contrast, as Myers (1989), Bazerman (1988) and others have pointed out, the research article is persuasive. This can be seen in every section, with the Introduction/survey of literature persuading the reader by placing the study in a light which makes it appear firstly as continuous as possible with previous studies in the field and secondly as answering an as yet unexplored area (Swales 1981). The Method section is persuasive within the culture of science in that it removes the researchers as agents, making the work done impersonal and thus objective. Ideally the Method persuades the reader that the methods used were free of distortion. The discussion section persuades the reader that (in the case of my data) the results are reliable and fit their theory, and that other interpretations of the data are not reliable.

The need for the writer of a research article but not of textbook to persuade the reader is related to the different power relations between reader and writer in research articles compared to textbooks. As Myers (1989) has pointed out, the readers of research articles, being representatives of the research community, are much more powerful than the writer is. On the readers depends whether the knowledge claim of the article is accepted, and thus becomes a fact, or not. By contrast the writer of a textbook is an authority on the subject compared to the reader, who is a relative neophyte. Textbook readers are assigned the textbook to read by the academic department they are studying with. That is, someone other than the readers has chosen the textbook based on their assessment of the suitability and completeness of its factual content. The student readers are thus encouraged to accept and learn the content of the textbook as fact. Thus, like the research article, the textbook has two sets of readers: students and the academics that prescribe the textbook. However, because the academic is assessing the textbook's suitability for students, neither writer nor the academics regard the academic as the primary projected reader of the textbook. The writer for example makes no attempt to mitigate the FTA of providing the academic with relatively elementary information There are no reader-oriented hedges. The writer assumes that the academic as reader will make his/her judgement of whether to prescribe the book based on accuracy and completeness of information provided, readability, tutorial questions (and answers), diagrams and photographs etc.

This power differential between reader (a student) and writer (an expert) is reflected in both hedging and in evaluation found in texts in the two genres. In the research article in the study, half the hedges are reader-oriented hedges (which serve to mitigate FTAs to readers). By contrast, in the textbooks, reliability hedges (which indicate writer confidence in a proposition) are most common, and there are no reader-oriented hedges, as the writers, being in a position of greater power relative to the readers, have no reason to mitigate FTAs. The authors of the research article avoid negative evaluation of their own ideas or methods (in order to persuade readers of the reliability of what they say), and also avoid negative evaluation of other writers (in order, as Myers (1989) points out, to show deference to the research community.) Textbooks show more overt evaluation, and this evaluation originates from the writer who is an authority.

Reader-oriented hedges in research articles reflect the writer's need to show deference to the reader who is, as Myers (1989) suggests, powerful in being the representative of the discourse community. By contrast, the dearth of reader-oriented hedges in textbooks reflects a writer who is an expert in the field, and is thus more powerful than the reader, generally a newcomer to the field. More than this, I have argued that, in summarising the ideas that currently have been accepted and endorsed as fact by the discourse community, the writer of the textbook is powerful in being a representative of, and speaking for, the discourse community. In the textbook the fact is reified. Reification involves 'representing a transitory historical state of affairs as if it were permanent, natural, outside of time' (Thompson 1990:65). My analysis in this section indicates that textbooks do indeed treat facts as outside time, although not, in this case, as permanent (it is clear from the three textbooks analysed that the topic is still controversial). In science, to be recognised as factual and objective, ideas must be removed from time and place and must be removed from the person who discovered them (Latour and Woolgar 1979). The textbook is the destination (perhaps temporary) of a successful knowledge claim from a research article that achieves this status. Textbooks transmit the collective knowledge of the discourse community, but as discourse they are less highly prized than research articles because the information they contain is not new information.

4.2.7 Summary and overview

In this sub-chapter I have characterised textbooks as similar to research articles in terms of register (context of situation), but different in terms of genre (context of culture). In both genres we can clearly recognise Halliday's (1993) 'cluster of features' that combine to produce scientific language: a high level of nominalisation, use of technical language, and impersonal language associated with a high level of passivisation. The most prominent register difference is the power differential between reader and writer in the two genres, with the reader of the research article and the writer of the textbook being more powerful. Associated with this is the persuasive intent of the research article, which is absent in the textbook. At the level of genre, differences between the two forms are marked. Research articles contain discussion, recount and exposition associated with the conventional Introduction-Method-Results-Discussion sections. By contrast, textbooks are likely to contain a good deal of information report, explanation and procedure, and these are not associated with particular sections but rather are used according to the need of the writer and the subject under discussion.

At the level of Ideology, I have argued that textbooks complete the process of objectification of facts that the research article has begun. The research article proposes a fact (knowledge claim) and hopes to convince the readers to endorse it as fact. To do so, the research article employs passivised, impersonal, nominalised language, with a high level of relational compared to material processes in order to remove it as much as possible from time, place and people (the writers). The removal of people /the researchers is incomplete (the author's name being attached to the article) until the fact is included in textbooks, which, employing the same passivised, impersonal, nominalised language, also bury mention of the researchers and instead reify the fact.

The next section is devoted to popular science articles, a genre that, like the research article and textbook, also prizes objectivity, but achieves it by stressing rather than removing the people concerned in research.

4.3: The popular science article: An article from Scientific American and comparisons with an article from Time.

4.3.0 Introduction

In 4.2 I analysed an extract from a first year textbook, drawing comparisons with a more advanced-level textbook and a textbook for non-science students. That analysis indicated wide similarities between the textbooks, particularly between the textbooks for first year and more advanced students. It also indicated a great deal of similarity between textbooks and research articles at the level of register. In this section of the chapter and the next I turn my attention to popular science articles. In 4.3 I report on my close examination of an article from Scientific American (cf. pages 23 and 25 of Appendix, which fold out), and draw comparisons with an article from Time magazine (cf. appendix page 28, 30 and 32). Both of these texts fall into the issues report genre (see 2.5.1). Scientific American is a publication which projects a readership largely made up of scientists, while Time, primarily a news magazine, caters to a much wider readership, who, for the most part, are not scientists. My analysis of the two texts indicates many similarities between them, and for reasons again of economy, I refer to the Time article only where it differs from the Scientific American article. In 4.4 I examine a popular article from the Mail and Guardian (cf. appendix page 35) which, unlike the other two popular articles falls into the opinion piece genre (see 2.5.1). I choose to examine this article in greater detail than the Time article, as it shows significant differences from the Scientific American and Time articles. I trace these differences to the different ideological stance towards science of the article compared to that of the other two articles. Briefly, the Scientific American and Time articles project a reader who is positive towards science while the Mail and Guardian article projects a reader who regards science in a negative light.

Because of the length of the Scientific American article (1500 words in total) I have fully analysed and report on only half the article, paragraphs 1, 3, 5, 8, 10, and 13 (748 words). However, in my consideration of theme, conjunctive relations and evaluation, in which continuity is important, I consider the entire article. As in chapters 4.1 and 4.2, I begin this account with a consideration of register, analysing Field in 4.3.1, Mode in 4.3 2 and Tenor in 4.3.3. In 4.3.5 I look at the context of culture, or genre, in the article and, finally, in 4.3.6, I consider the ideology in the Scientific American article.

4.3.1 Field in the Scientific American article

In this section I consider human participants, processes and participants, and circumstances. In general terms, there is strong focus in this article on researchers and what they do and say. In this respect the text is similar to the Time article. However the Scientific American article also has similarities with the textbooks reported on in 4.2, in that the theories of researchers and evidence for these theories are also prominent.

4.3.1.1 Human participants in the Scientific American article

This article from Scientific American bristles with human participants (17), almost all of whom are researchers and authors of the research articles on which this article reports. Table 4.3.1 shows that more than half the human participants are the subject of major clauses, indicating that the Scientific American article is about researchers and their ideas. In fact the text is framed as a report on a debate between different researchers. Table 4.3.2 shows that there are even more human participants in Time. The large number of human participants in these texts coincides with Bakhtin's characterisation (cited by Lemke 1992.85) of texts as multivocal In both texts most human participants are specific (rather than generic), evidence that these are real people who are acting and being quoted – not merely 'most scientists' or 'some researchers' as in the textbooks. Similarly, in both texts most human participants are major in status meaning that they appear as participants rather than as part of a circumstance. Thus the text is about real specified scientists, and what they think, say and do. The scientists are the focus of these articles (not dinosaurs as in the children's texts or ideas as in the textbooks). The specific and major status of scientists in Scientific American and Time contributes to the positive image of science and scientists projected by the article. There is nothing sinister or threatening about these scientists or their research.

Table 4.3.1 Human participants in the Scientific American article

2a	the scientific and popular press	(circumstance)	minor, generic
5a	the Berkeley workers	proposed (*verbal*)	minor, specific
5a	David M Raup and J John Sepkoski Jr of the University of Chicago	an analysis ... done by (*material*)	minor, specific
6a	they (Raup and Sepkoski)	determined the rate of extinction (*mental*)	major, specific
9	Raup and Sepkoski	suggested (*verbal*)	major, specific
10	Daniel P Whitmire of the University of Southwestern Louisiana and ...	proposed models (*verbal*)	major, specific
14b	an editor at *Nature*	selected (*material*)	minor, specific
14b	Muller and his colleagues	were considering (*mental*)	minor, specific
15	Hoffman	points out (*mental*)	major, specific
15	Raup and Sepkoski	pared down (*material*)	minor, specific
18a	Hoffman	restored (*material*)	major, specific
19	Hoffman and Joe Ghiold of ...	suggest (*verbal*)	major, specific
19	Raup and Sepkoski's criterion	is biased (*attributive*)	minor, specific
22b	Hoffman and Joe Ghiold	apply it (definition) (*material*)	major, specific
25a	Hoffman's arguments	do not rule out (*material*)	major, specific
26	Raup and Sepkoski's data (goal)		minor, specific
26	Hoffman	found (*mental*)	major, specific

The processes used in Scientific American are fairly neutral reporting verbs. Two exceptions (in bold-face in the examples) both apply to Raup and Sepkoski, with whose research the author of the Scientific American article disagrees. Raup and Sepkoski are said to have 15b***pared down*** *their data*, indicating a somewhat faulty piece of research. Even worse, is the fact that their 19b***criterion is biased***.

Table 4.3.2 Human participants in research article, textbook and popular articles

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	*Mail & Guardian*
Number of participants	4	4	11	6	17	56	8
Major/minor	Major	major	Minor	Major	Major (+ minor)	Major	Major
generic/specific	specific	generic	Specific (+ generic)	generic	specific	specific	Generic
Human participants personalised				✓	✓	✓	

Table 4.3.2 depicts a comparison I make between popular texts, research articles and textbooks concerning who is given a voice. Another factor reflected in it is whether that voice reflects written or spoken voices. Research articles privilege the written and published voices of other scientists (Ivanic and Simpson 1992). Besides this, research articles focus on their own rather than other people's research. Textbooks, although they cite some published works, are more commonly 'peopled' by generic representatives of the discourse community (e.g. '*Some palaeontologists*' in Duff) or by researchers who have been omitted by use of the passive (e.g. [11]*Much attention has been paid to the Cretaceous/Tertiary (K/T) boundary* (Duff).) By contrast the Scientific American and Time texts foreground researchers: what they think and say and how they engage in their research. The Scientific American article sets up a dialogue between them, making a judgement about which findings and claims are most convincing. The difference is also a function of the different readers of the texts - a much broader readership in the case of the Scientific American article, and readers who are scientists but are not geologists. The majority of readers of Scientific American are the exoteric audience (Myers 1989:3) that "takes an interest in some of the researchers' findings" compared to the readers of Raup and Sepkoski who have a far greater chance of being the esoteric audience "involved in the ongoing research problem". However the scientists involved in the ongoing research problem (Myers' esoteric audience) are very much present in the article as the authorities quoted by the writer. It is on their utterances that the writer of a popular science news article scaffolds his/her argument

The first time the human participants are mentioned in the Scientific American and Time articles, their first name, initial, surname and associated research institution are included. This is different from Raup and Sepkoski (1984) where the person's surname only is used. Ungerer (1997:315) suggests that use of titles and 'endearing forms of address' are linguistic cues likely to trigger emotion and interest in news stories, and it may be that use of first name and associated institution is similar to this. We get a glimpse of them as being real people. However the stress on their associated institutions also signals that they are also in a sense members of an elite. This attribution of ideas and utterances to elite authorities bolsters the authority of the writer.

The large number of human participants in this text, almost all of them specific and more than half of them the subject of major clauses, collocate with material, mental and verbal processes. This indicates a text that is about what specific researchers think, say and do. The text is a summary of the conflicting knowledge claims of different researchers for the exoteric audience (Myers 1989) who take an interest in scientific findings in fields other than their own. Human participants are personalised to the extent that their first names and associated institutions are mentioned. As the scientists active in the field under discussion, the human participants in popular science articles are the quoted authorities. By quoting these accredited authorities the writer of the article gains authority for what is said. This is bolstered by reference to the authorities as associated with elite institutions.

4.3.1.2 Processes, participants and circumstances in the Scientific American article

As in the companion accounts in 4.1.1.2 and 4.2.1.2, this section reports on what the Scientific American text is about as reflected in the participants and processes. In brief, the article is about researchers (who constitute most sensers and sayers) and their research (their hypotheses, methods, results, conclusions and knowledge claims). Thus the information in the article reflects its origins in the research articles from which the writer presumably extracted the information.

As with Raup and Sepkoski (1984) the lexis in the Scientific American article reflects a world in which mass extinction and life under threat from extraterrestrial forces are well-accepted possibilities. Once again the ability to reflect on remotely distant events, as represented in the fossil record, is accepted as axiomatic. However, unlike in Raup and Sepkoski (1984), the idea of periodic mass extinction having an extraterrestrial cause is treated with some irony, being variously referred to as:

[1]***The notion*** *that* ***extraterrestrial forces*** *have...;* [2a]***In the scenario*** *that has* ***received the*** *most attention...;* [2a]***a dim distant*** *companion star of the sun ...;* [3]***putative*** *star;* [25b]***celestial intrusions***.

In treating the topic ironically, the writer distances him/herself from the "*notion*"/"*scenario*" of periodic mass extinctions being caused by extraterrestrial forces. The ironic treatment and mention of popular publications constitute an awareness of its sensational implications. Besides this, Raup and Sepkoski (1984) are represented as using faulty research methods:

Raup and Sepkoski [15b]***pared*** *... their original data* ***down*** *...;* the [16]***culled their data*** ....
Even worse, their criterion is said to be [19b]***biased*** and [20]***not quantitative***.

Researchers and their associated institutions feature strongly in the Scientific American article. Both scholarly publications (Nature and Geological Magazine) and popular publications (the New York Times and Time) are important.

Table 4.3 3: Processes and participants in the Scientific American article

parag	clause	Actor	Material	Goal	Circumstance
1	2b *		to send	periodic showers of comets	into the inner solar system
1	2c *	some of the comets	strike	the earth	
1	4 *	the regular extinctions	may never have taken place		
3	5a @	the impetus	came		in late 1983 in the form of...
3	7 #	The rate	peaked		regularly at intervals of ...
5	11a *	The companion	would lie		at a distance of several light years
5	12 *	the star	would pass through	the dense inner region of ..	Every 26 million years, at ...
5	14b *	an editor at *Nature*	selected	it	from a list of possibilities ...
5	15b #	Raup and Sepkoski	pared down	the 3500 families in their original data	to 567 by removing families
8	18a#	Hoffman	restored	the omitted families	to the data
8	18b #	many ... extinction peaks	disappeared		
10	22b #	Hoffman and Joe Ghiold	apply	it	To a hypothetical model ...
13	27	the ... disruption of the biosphere	continue to make	a powerful case	for an isolated impact's having...
		Senser	**Mental**	**Phenomenon**	**Circumstance**
3	6	they	determined	the rate of extinction	For each stratigraphic stage...
10	22a β		to analyse	the effects of that definition	
13	26a	Hoffman	found	FACT (that the final stage of ...)	In applying various statistical criteria to...
		Sayer	**Verbal**	**Verbiage/Range/ target**	
1	2a		is held	a dim distant companion star ...	In the scenario...
1	4	A reassessment of the fossil evidence	suggests	FACT (the regular extinctions ...)	
3	9a	Raup and Sepkoski	suggested	FACT (that the periodicity reflects..)	
5	10	Daniel P Whitmire ...	proposed	models	simultaneously
8	15a	Hoffman	points out	FACT (R&S pared the 3500 families ...)	
10	19	Hoffman and Joe Ghiold ...	suggest	Fact (that R&S's criterion...is biased)	In another line of argument ||presented

		Identified	Identifying	Identifier	Circumstance
1	2d		causing	a mass extinction of species	
1	3	the proposal	has been	the subject of newspaper articles...	
3	9	the periodicity	reflects	a recurrent event ...	in the physical environment
5	13	The gravitational influence of ...	*would precipitate*	a comet shower	
5	17	it (culling of data)	meant	that FACT	
10	21	an episode of mass extinction	is	any local peak in extinction rate:	
10	23a	the probability that ...	is	one half	For each stage
10	23b	the likelihood of ...	is	one half	
10	24	the probability that	is	one in four	
10	25a	Hoffman's arguments	do not rule out	the possibility that ...	
		Carrier	**Attributive**	**Attribute**	
1	1		gained	wide currency	a little more than a year ago
3	8	statistical tests	indicated	a weaker periodicity of 30 million years	
5	11b	its orbit	would be	eccentric	
5	14a	(The star	got	its name	
10	19		is	biased	towards periodicity
10	20	The criterion	is not	quantitative	
13	25b	they	*make* (it)	unnecessary	
13	26	the final stage of ...	qualified	as a mass extinction	

* relates to meanings in the real physical world] see
# relates to meanings to do with the world of research] Table 4.3.5
@ relates to ideas] below

Material processes

The material processes and participants in this article deal with four sets of meanings: the Nemesis Hypothesis, how the researchers did the research, their findings, and their conclusion. Thus the material clauses reflect the sections of the research article: hypothesis, methods, findings and conclusion.

Hypothesis:

held [2b]*to send periodic showers of comets into the inner solar system, where ...*; [11a]*The companion would currently lie at a distance of several light-years*; [12]*the star would pass through the dense inner region of the Oort cloud.*

Methods:

[15b]*that Raup and Sepkoski pared the 3500 families in their data down to 567 by...*
[18a]*When Hoffman restored the omitted families to the data*; [22b]*Hoffman and Ghiold apply it to a hypothetical model in which ...*;

Results:

[7]*The rate peaked regularly at intervals of about 26 million years*;
[18b]*many of the sharpest extinction peaks disappeared*;

Conclusion

[4b]*the regular extinctions said to be the handiwork of Nemesis may never have taken place.*

This gives the impression that what the article is about is research – what its writers hypothesise, how the research was done, and what was found. Implications for both life on earth and the extraterrestrial forces that influenced it are embedded within nominal groups and are elaborations on them.

Mental and verbal processes

The sensers and sayers associated with mental and verbal processes are almost all researchers. The article gives us insight into the thoughts of the researchers and allows us to hear what they have to say:

[6]*...they **determined** the rate of extinction (**defined** as the number of families that ...)*; [22a]***To analyse** the effects of that definition, Hoffman and Ghiold ...*; [26a]*Hoffman **found** that ...*; [9a]*Raup and Sepkoski **suggested***; [10]*Daniel P Whitmire ... **proposed***; [15]*Hoffman **points out***; [19a]*Hoffman and Ghiold **suggest**.*

There are far more reporting verbs in the Scientific American article than there are in Raup and Sepkoski and the textbooks, from which they are almost absent. In the Scientific American text some of the reporting verbs are consistent with the reporting-on-research function of the article:

[28]*Alvarez ... **reported** that*; [32a]*The workers **proposed** that*; [9a]*Raup and Sepkoski **suggested***; [36a]*Rampino and Stothers... **proposed***; [10]*Richard A Muller... **proposed** ...*

Other verbal processes are consistent with arguing between opposing explanations: [40a]*some workers **argue** that*; [42a] *Antoni Hoffman... **contends** that*; [15a]*Hoffman **points out** that*; *Hoffman and Ghiold **suggest** that...*; [48a]*Hoffman **argues**...*; [51]*Raup and Sepkoski **stand by their finding***; [42a] *Sepkoski **also found***; [55]*Hoffman **found**.*

These examples reveal that on the whole the writer is on the side of the argument put forward by Hoffman rather than on the side of the argument supported by Raup and Sepkoski. Hoffman is far more often said to be '*arguing*', '*contending*', '*pointing out*', etc. than are Raup and Sepkoski, who, however, have two such verbal processes associated with their names. The writer thus attempts to present a balanced case in which Raup and Sepkoski '*stand by*' their findings and '*also found*' supporting evidence for their ideas. This enables the writer to create the appearance of objectivity.

Further evidence for the writer's support for Hoffman over Raup and Sepkoski is found in the explicit statement in the writer's conclusion that it is "[25b]*unnecessary to suppose the celestial intrusions have been regular*", and in the final clause complex of paragraph 1: "[4a]*A reassessment of the fossil evidence now suggests the regular extinctions ... may never have taken place*". This use of reporting verbs means that the writer stays at arm's length from the argument. It is Raup and Sepkoski, or Hoffman that are arguing, suggesting and pointing out; on occasion even the research itself makes suggestions: "[4a]*A **reassessment** of the fossil evidence now suggests*". Thus the writer very skilfully allows the researchers to speak for him/her. Combined with use of modality discussed below, the article appears objective (both sides of the argument presented) but the writer signals the side of the argument s/he finds more convincing through modality, process verbs and explicit statement.

Below (cf. 4.3.2.1) I argue that this text is a narrative of research. However the text goes beyond this to be a narrative of rival knowledge claims. The verbal and mental processes combine with nominalisations of verbal and mental processes (e.g. [4a]*reassessment*) and other nouns meaning something like 'idea' or 'claim' (e.g. [4]*notion*, [27]*the case*) to make almost every clause of the text participate in tracking what was claimed and what the status of the claim is in the opinion of the writer. I illustrate this by reference to paragraph 1 and 2 only.

[1]*The notion ...* [2a]*In the scenario ...* [3]*the Nemesis hypothesis ... the proposal has been the subject of newspaper articles, two editorials in the New York Times and a cover story in Time magazine.* [4a]*A reassessment ... now suggests* [4b]*the regular extinctions said to be the handiwork of Nemesis ...*

[28]*Nemesis and similar theories grew out of an earlier and more modest claim.* [29a]*Luis W. Alvarez, ... reported ...* [32a]*The workers proposed ...* [33]*Since then the finding ... have bolstered the case ...*

Fact Clauses

Gerot (1995:96) suggests that packaging information as facts implies that these facts have a privileged, accepted status. There are a number of mental (1) verbal (4) and identifying (1) fact clauses in this article. An example of a fact clause in the Scientific American article is: [17]*But it also **meant** that small fluctuations in extinction rate during recent stages would be magnified by* ... Those facts in clauses 4, 9 and 26 constitute the knowledge claim of research articles (those of Raup and Sepkoski in 9 and of Hoffman in 4 and 26). The facts in clauses 15, 17 and 19 are Hoffman's criticisms of Raup and Sepkoski's findings/claims. Five of the six fact clauses express Hoffman's rather than Raup and Sepkoski's point of view, supporting the idea that the writer sides with Hoffman rather than Raup and Sepkoski. (This is likely to be a news bias to the most recent findings as much as a bias in favour of Hoffman or against Raup and Sepkoski). In the Time article, much of the explanation of the theories associated with the impact hypothesis is contained in fact clauses, indicating once again that information imported from other texts is often contained in fact clauses.

Relational processes

There are far more relational processes in this text than there are other types of processes, reflecting a text primarily about relationships between things: what causes what and how likely different ideas on the topic are to be true. Many of the relational processes in this text involve causal verbs, which often join two nominalised processes together:

The gravitational influence of Nemesis	*would precipitate*	*a comet shower*
nominalisation	causal verb	nominalisation

Conjunctions and prepositions are the typical way that logical-semantic relations are constructed in English, but the lexicalisation of cause as verbs is a feature of scientific writing, as is lexicalisation of cause as nouns (nominalisation) (Halliday 1993:92).

Embedded meanings in the Scientific American article.

Table 4.3.4 shows the meanings realised in embedded clauses in the article.

Table 4.3.4 Meanings in embedded clauses in the Scientific American article

	Actor	Material	Goal	
1i @	extraterrestrial forces	have intruded into	the history of life	
2ai @		has received	the most attention	in the ... press
5i @		to extend	the isolated event ...	into a cycle of ...
5iii *	by David M Raup ...	done		
6i #		is divided	the fossil record ...	into which
6ii #		defined		as the number of families ...
6iii #	by the number of families existing ...	divided	the number of families that became extinct ...	
12ii*		to envelop	the solar system	
15bi #		cannot be resolved	whose origin and extinction	to single stages
17i #	by the reduced number of ...	would be magnified	small fluctuations in extinction rate ...	
22bi #	the rate [at which...]	varies		at random from stage to...
25a @	.... influences	have shaped	the history of life.	
26ai #		applying	various statistical criteria	range: to R & S's data
27i *	that	occurred		then
27ii *		having ended	the reign of the ...	
	Senser	**Mental**	**Phenomenon**	
12i		is thought		
25bi		to suppose		
	Sayer	**Verbal**	**Verbiage/Range/ target**	
4bi		said		
5ii	by the ... workers	proposed		
	Identified	**Identifying**	**Identifier**	**Circumstance**
3i		Called	the Nemesis hypothesis	after the name of the .. star
4bii		to be	the handiwork of ...	
10i	the extinction periodicity	reflects	the orbital period of a companion star ...	
16i	from the fact that...	resulting		
16iii	they	may represent	.. similar ... groups	
24i	the stage	represents	a peak in extinction rate	
	Carrier	**Attributive**	**Attribute**	
6iv		became	extinct	in the stage
21i	the rate	is	higher than in the preceding ...stages	
22bii	families	become	extinct	
23ai	the extinction rate	is	higher than in ...	
23bi	its	being	higher than in the following stage	
25bii	the .. intrusions	have been	regular.	
	behaver	**behavioural**	**matter**	
16ii		are classified	many recent fossils	as members of ... groups
19bi		identifying	a mass extinction	

* relates to meanings in the real physical world
\# relates to meanings to do with the world of research
@ relates to ideas
Roman numerals indicate embedded clauses. For example 25bii refers to the 2nd embedded clause in clause 25b.

Table 4.3.5 summarises the differences in kinds of meaning realised in ranking compared to embedded clauses. Differences between ranking and embedded material clauses in the kinds of meanings realised, are not as striking as in the textbook, McGhee, which has meanings to do with the real world and research in embedded clauses compared to abstract meanings in ranking clauses. In the Scientific American article there are more real world meanings and fewer abstract meanings in the ranking clauses than in the embedded clauses. This seems to be because the embedded material is more likely to have been imported from another text (i.e. a research article). Most processes and participants that concern the extraterrestrial forces and all the meanings to do with implications for life on earth are contained in embedded clauses. Extraterrestrial forces or bodies: [1]*intrude*, [2c]*strike*, [25a]*shape the history of life*, [27]*end the reign of the dinosaurs*, as well as the less threatening [11a]*lying at a distance of ...* and [12]*passing through the Oort cloud*. Life and living things, [1]*history of life*, [6]*fossil record*, [6]*families*, [27]*dinosaurs* are [1]*intruded upon*, [25a]*shaped* and [27]*ended*, by the extraterrestrial forces. The circumstances associated with material forces are to do with time and place, mainly the time and place of these events initiated by extraterrestrial forces.

Table 4.3.5 Summary of kinds of meanings in ranking and embedded clauses

	Real world meanings	Research meanings	Abstract meanings	total
Ranking material clauses	6 (50%)	5 (42%)	1 (8%)	12
Embedded material clauses	4 (27%)	7 (47%)	4 (27%)	15

Circumstances

Table 4.3.6 indicates that circumstances of location are most prominent in this article.

Table 4.3.6 Circumstances in the Scientific American article

Extent: temporal	Location: place	Location: time	Manner	Cause	Contingency	Role	Matter	
1	**8 (38%)**	**3 (14%)**	**3 (14%)**	1	1	1	**4 (19%)**	21

Such circumstances (specifically of location) refer to where things happened, in terms of astronomy, ([11a]*at a distance of several light years*; [12]*at its closest approach to the sun*), or where in abstract space ([14b]*an editor selected it from a list of possibilities*; [22b]*they apply it to a hypothetical model*). Circumstances of location in time refer to when discoveries were made or research done such as [5a]in late 1983. These circumstances combine with a number of marked themes to make the article into a narrative of how research in this area has progressed. Unusually in the texts in the study, matter is also important. These refer to theories ([2a]*In the scenario that has received the most attention in the scientific and popular press*) and stratigraphic stages ([6]*For each stratigraphic stage into which the fossil record of the past 250 million years is divided*).

4.3.1.3 Summary and overview of Field in the Scientific American article.

As in the Time article there are a large number of human participants in the Scientific American article, indicating a text that is far more personal than the research article and the three textbooks considered. Most of the human participants are specific and half are the subject of major clauses collocating with mental, verbal and material processes indicating that the text is about researchers and their conflicting knowledge claims. By comparison with the article in the Mail and Guardian researchers collocate with most of the verbal processes and thus they are given the major voice in the article. Use of verbal processes such as 'contend' and 'argue' allow the writer to stand back from the argument and appear objective. Because the human participants are researchers active in the field, their utterances and the fact that they are in a sense elite people give the article authority. Not only is the article authoritative, but the writer also gives the impression of being objective in that the researchers appear to be arguing while the writer appears to be neutrally reporting what they say. These verbal processes combine with circumstances of time to make this article a narrative of contending knowledge claims. By contrast with the textbook by McGhee, in the Scientific American text it is the abstract information rather than the real-world information that is likely to be located in embedded clauses. This makes the abstract meanings less easily challenged by the reader. The verbal processes in this text make it into a debate between rival research claims.

4.3.2 Mode in the Scientific American article

In this section I consider, under the categories of theme, nominalisation and embedding, passivisation and conjunctive relations, the ways in which the author of the Scientific American article has chosen to organise the message.

4.3.2.1 Theme in the Scientific American article

Table 4.3.7 provides a clause by clause analysis of theme in Scientific American. In the fourth column of the table I signal the markedness of themes using Gosden's (1992) categories. Like the research article and textbooks in this study, the Scientific American article also wishes to appear objective, and in the value system of journalism this means giving "both" sides of the story. This the article does, but by skilful use of marked themes, amongst other things, the writer signals to the reader that 'one side of the story' is more credible than the other.

Table 4.3.7 Theme in the Scientific American article

	Textual	Topical	markedness
1		The notion ((that extraterrestrial forces have ...intruded ...))	'heavy' theme
2a		In the scenario ((that has received the most *attention* in ...))	Location in space
	where	Some of the comets	
3		**Called the Nemesis hypothesis after the name of the ....**	Preposed attributive
4a		A *reassessment* (of the fossil evidence) now	
4b		the regular extinctions said to be the handiwork of Nemesis*	
28		Nemesis and similar theories	
29a		In 1979	Location in time
29b	that	a layer of clay [[deposited at the end of the Cretaceous about 65 million years ago in Italy, ...]]	'heavy' theme
30a		Iridium	
30b	but		contrast
31		Widespread extinctions, [[including the demise of the dinosaurs]]	
32a		The workers	
32b	that	the extinctions and the iridium layer	
33		Since then	Location in time
5a		The impetus ((to extend the isolated event ((proposed by the Berkeley workers))))	'heavy' theme
6		For each stratigraphic stage ((into which the fossil *record* of the past 250 million years is divided))	Location in space: 'heavy' theme
7		The rate	
8		Statistical tests also	
9a		Raup and Sepkoski	
9b	that	the periodicity*	
34		Astronomers and astrophysicists	
35		In several scenarios	Location in space:
36a		Michael R Rampino and Richard B Stothers of ...	'heavy' theme
36b	for example that	during passages through the galactic plane, [[which occur at intervals of about 33 million years]]	Location in time Addition: appositive 'heavy' theme
10		Daniel P Whitmire of the University of Southwestern Louisiana and Albert A ...	'heavy' theme
11a		The companion	
11b	but	its orbit	contrast
12		Every 26 million years, at its closest *approach* to the sun,	Location, time & space
13		The gravitational influence (of Nemesis)	
14a		The star	
14b	when	an editor at *Nature*	Location in time
37a		*Support* for the notion of periodic impacts	
37b		other geologic events [including reversals in the earth's ...]	'heavy' theme
38		The proposed mechanisms	
39		**It appears, for example,**	

40a		As for the Nemesis model,	matter
	that	a companion star |at the great distance [[that is required]] |	'heavy' theme
41		Now	Location in time
42a		In a recent paper in *Nature*	Location in space
42b	that	uncertainties (in fossil dating and biases in R &S's methodology)	'heavy' theme
15a		Hoffman	
15b	that	Raup and Sepkoski*	
16		The culling (of the data)	
17a	But	it [culling of the data]	contrast
18a		**When Hoffman restored the omitted families to the data**	Location in time
43		The original *finding* of *periodicity* also	
44		Equally plausible time scales ...	
45		**Given a time scale ((different from the one R and S adopted,))**	concession
19a		In another line of argument ((presented in a paper in ....))	Location in space
19b	that	Raup and Sepkoski's criterion for identifying a mass extinction*	
20		The criterion	
21	Instead	an episode of mass extinction	contrast
22a		**To analyse the effects of that definition**	Clause as theme Cause: purpose
23a		For each stage	Location in time
23b		the *likelihood* ((of its being higher than in the following stage))	'heavy' theme
24		The *probability* ((that the stage represents a peak in extinction ...))	'heavy' theme
46	Even if	extinction rate varies randomly,	concession Clause as theme
47		In the time scale Raup and Sepkoski adopted	Location in time
48a	Hence,	Hoffman	Cause: result
48b		R & S's *definition of mass extinction*, together with their time scale,	
49a		There may	
49b	but	the *regularity*	contrast
50	**If it is,**		Clause as theme Condition: hypothetical
51		Raup and Sepkoski	
52a		In their original work	Location in space
52b	and		
53a		The 26-million-year cycle	
53b	which		
53c	that	it	
53d	and		
54a		Since then	Location in time
54b		the 26-million-year periodicity	
55		Sepkoski	
56		Reports of both new analyses	
25a		Hoffman's arguments	
25b	even if	they	concession
26a		In applying various statistical criteria to Raup and Sepkoski's data	Cause: purpose
26b	that	the final stage of the Cretaceous	
27		The ... *disruption* ... ((that occurred then)) and the iridium layer	'heavy' theme

nominalisation: italics; **clause as theme: bold**; marked theme: underlined

Table 4.3.7 indicates that thematic development of the Scientific American article is achieved through marked themes, largely circumstances and 'heavy' themes (listed in the fourth column), and also through some maintenance of theme (marked by arrows in the second column). In general the circumstance as marked themes in the Scientific American article can be divided into two groups. Firstly there are those that concern where and when events have happened in remote time and space: [36b]*during passages through the galactic plane*; [12]*Every 26 million years, at its closest approach to the sun*. These marked themes combine with circumstantial adjuncts in unmarked clausal positions to paint a picture of events that are extremely far off in both time and space: [1]regularly and catastrophically; [2a]into the inner solar system; [7]at intervals of about 26 million years; [11a]at a distance of several light years; [19]towards periodicity.

Secondly, there are those marked themes that concern recent time and space: when research took place, the models and methods researchers used, and where and when they published the work:

[2a]*In the scenario ((that has received the most attention in the scientific and popular press))*; [29a]*In 1979*; [33]*Since then*; [6]*For each stratigraphic stage ((into which the fossil record of the past 250 million years is divided))*; [35]*In several scenarios*; [40a]*As for the Nemesis model*; [42a]*In a recent paper in Nature*; [19a]*In another line of argument ((presented in a paper in Geological magazine.))*; [47]*In the time scale Raup and Sepkoski adopted*; [52a]*In their original work*; [54a]*Since then*; [26]*In applying various statistical criteria to Raup and Sepkoski's data*.

It is clear that these adjuncts keep drawing the readers' attention to the research, its methods and theories. In many cases this is preparatory to mentioning criticism of Raup and Sepkoski's work. These marked themes combine with a number of circumstantial adjuncts used in the article to make the text into a narrative of how research in this area has progressed:

[5a]*in late 1983*; [1]*a little more than a year ago*; [2a]*in the scientific and popular press*
[14b]*from a list of possibilities ((Muller and his colleagues were considering))*

For the most part, the marked themes in this article function to signal the progression of a narrative of research into the idea of an extraterrestrial cause of mass extinction. They signal what researchers are involved, when and how they did the research, what their basic findings were, the controversies between researchers and ultimately which researchers the writer thinks are right.

Besides all the circumstances of time and space as marked themes there are also many marked 'heavy' themes. According to Thompson (1996:141) a common function of these is also to specify the framework for interpretation.

Almost every paragraph has a heavy theme in the first clause or a circumstance of time and space in the second clause or a combination of these. The writer uses these two devices to specify the framework for the interpretation of the paragraph (Thompson 1996:141). Examples of paragraphs that have the combination of heavy clause followed by circumstance are paragraphs 1 (clause1 and 2a), 3 (clause 5 and 6a), 4 (clause35 and 36a), and 11 (clause 46 and 47).

The large number of marked themes – circumstances of both time and space, and 'heavy' themes – indicate that the writer is keen to keep specifying the framework for interpretation, and to guide the reader closely in interpretation of the text. This close guidance in telling the reader what is important in the text, and how to interpret the text, coincides with the structure of the text, which is only **apparently** a debate structure. As discussed above in section 4.3.1 closer reading indicates that the writer is clearly in support of one of the voices (Hoffman) rather than the other (Raup and Sepkoski).

Apart from the use of marked themes in structuring the text, as the arrows in the Table 4.3.7 show, the writer uses a mixture of maintenance of theme (same theme as the previous one) and progression of theme (theme drawn from the previous rheme) throughout the text.

In summary, the analysis of theme above indicates that the writer of this text guides the reader very closely in the interpretation of this text. To do this the writer combines use of 'heavy' theme in the first clause of a paragraph with marked theme in the form of circumstances of time and space in the second clause of each paragraph. As I suggest above, this signals to the reader what is important in the text and how to interpret the text. This close guidance supports my suggestion elsewhere that the text only apparently gives equal voice to the two rival knowledge claims/voices in the text. In fact the writer clearly supports one of the voices and gives little credence to Raup and Sepkoski.

4.3.2.2 Nominalisation and embedding in the Scientific American article

Nominalisation turns a process into a thing and locates it in the nominal group. Embedding extends the nominal group, but locating a phrase or clause within it.

Nominalisation in the Scientific American article

In this article nominalisation (cf. sections 4.1.2.2 and 4.2.2.2) is more common than it is in the other two popular articles in the study. This may reflect a readership of a greater proportion of scientists than the readership of Time or the Mail and Guardian.

In the Scientific American text, 27 different nominalisations were found in about 900 words of the text (paragraphs 1, 2, 3, 5, 8, 10 and 13). I will discuss these under two categories: those that function in the narrative of research in the text and others as part of cause and effect argument in this very closely argued text.

Nominalisations that function in the narrative of research

[2a]*attention*, [3]*hypothesis*, [3]*proposal*, [4a]*reassessment*, [28]*claim*, [33]*finding*, [5]*analysis*, [19a]*argument*, [21]*definition*, [25a]*arguments*

They function as part of the narrative of research and rival knowledge claims discussed above. They combine with nouns like [1]*notion* and [2a]*scenario* to allow the author to track what is being claimed and the status of the claim in the writer's opinion. Of these, some ([3]*hypothesis*, [3]*hypothesis*, [4a]*reassessment*, [33]*finding*,) avoid mention of agent. Most of these are in the introductory paragraph that provides a broad sketch of what is to come. Their function does not therefore appear to be concealment of agent. Other nominalisations ([2a]*attention*, [28]*claim*, [5]*analysis*, [19a]*argument*, [21]*definition*, [25a]*arguments*) mention the agent in the same or a previous clause.

Nominalisations that function in cause and effect argument

The second and more numerous category of nominalisation involves processes and attributes that have been transformed into nouns. These nominalisations function in cause and effect argument as descibed by Halliday (1993:61):

[1]*currency*, [4a]*evidence*, [33]*anomaly*, [6,15b,19b,24]*extinction*, [8,9b,10,19b]*periodicity*, [12]*approach*, [16]*culling*, [16]*uncertainty*, [17]*fluctuations*, [23a,24]*probability*, [23b]*likelihood*, [25a]*possibility*, [25b]*intrusions*, [27]*disruption*, [27]*reign*.

Two further nominalisations are adjectives that are used as nouns – in fact abbreviations:
[31]*Cretaceous [period]*, [14a]*possibilities [possible explanations]*.

The Scientific American article is shown in Table 4.3.8 below to have a significantly larger number of nominalisations than the other two popular texts, perhaps a reflection of the greater knowledge of science of the readership of Scientific American. The readers of the Mail and Guardian and Time are not expected to be scientists as the readers of Scientific American are. The high number of nominalised mental and verbal processes supports the idea of this text as a narrative of rival knowledge claims. Not surprisingly, compared to Raup and Sepkoski and Duff, none of the popular texts uses nominalisation to avoid mention of agency. As my discussion of human participants and passivisation shows, popular texts have no motive to avoid mention of agency, as impersonalisation is not how objectivity is achieved in news articles. Instead, the writer achieves both objectivity and authority by attributing ideas to human participants and using them to construct his/her argument.

Table 4.3 8 Number and function of nominalisations in the different texts

	R & S	Duff	McGhee	T&H	Scientific American	Time	*M & G*
Different nominalisations per 1000 words	43	56	45	7	30	20	18
Number of nominalised mental & verbal processes/ 1000 words	5.6	5.6	5.4	3.6	11.1	3.0	6.1
Technical terms	✓	✓	✓	✓	✓	✓	-
Cause and effect argument and keeping reasoning in same clause	✓	✓	✓		✓	✓	
Mention of agency avoided	✓	✓					

In brief, the nominalisation in this article functions in constructing the argument over whether research into an extraterrestrial cause for mass extinction is convincing. The first involves nominalisation of mental and verbal processes such as [4a]*reassessment* and [5]*analysis*. By becoming actors in the text these function in making this text a narrative of rival knowledge claims. The second type of nominalisation functions in facilitating efficiency in argument..

Embedding in the Scientific American article

This text is highly embedded, and the embedding serves the function of adding specificity, adding detail, and adding intertextual information on which the ranking clause can comment.

1. Embedded material that adds to the specificity of what is said

[31]*Widespread extinctions, [including the demise of the dinosaurs,] marked the end of the Cretaceous*
[32b]*the extinctions and the iridium layer had a common cause: the impact of an extraterrestrial object, [probably an asteroid about 10 kilometers in diameter.]*
[9b]*the periodicity reflects a recurrent event, [probably of astronomical origin,] in the physical environment.*
[6]*For each stratigraphic stage [[into which the fossil record of the past 250 million years is divided]] they determined the rate of extinction [[(defined as the number of families that became extinct in the stage divided by the number of families existing during the stage).]]*

2. Sometimes this addition of greater specificity shades into the addition of detail:

[5]*The impetus to extend the isolated event ... came in late 1983 in the form of an analysis of stratigraphic data on fossil marine animals [[done by David M Raup and J John Sepkoski Jr. of the University of Chicago.]]*
[36a]*Michael R Rampino and Richard B Stothers [of the National Aeronautics and Space Administration's Goddard Institute for Space Studies] proposed...*
[14a]*(The star got its name* [14b]*when an editor at Nature selected it from a list of possibilities [[Muller and his colleagues were considering.)]]*

3. Evaluative authorial comment (bold face) in ranking clauses on intertextual embedded information:

[1]***The notion** that [[extraterrestrial forces have regularly and catastrophically intruded into the history of life]] gained wide currency...*
[2a]***In the scenario** [[that has received the most attention in the scientific and popular press]]...*
[3]*[[Called the Nemesis hypothesis after the name of the putative star]], **the proposal** has ...*
[33]*Since then **the finding** that [[an iridium anomaly exists at many other sites around the world and that the iridium-rich clay also contains minerals apparently altered by heat and shock]] **have bolstered the case**...*
[10]*Daniel P Whitmire ... and Albert A Jackson ... **proposed models** [[in which the extinction periodicity reflects the orbital period of a companion star of the sun.]]*
[17]*But **it also meant** that [[small fluctuations in extinction rate during recent stages would be magnified by the reduced number of families under consideration.]]*
[25a]***Hoffman's arguments do not rule out the possibility** that [[extraterrestrial influences have shaped the history of life]]...*

What is said in this article from Scientific American seems to be at several removes from the author, who develops an argument something like: 'researcher *x*, reporting in journal *a* reports finding *p*. However researcher *y*, reporting in journal *b* disagrees with finding *p* because of *q*'. Thus a lot of the embedding in the article is a result of the fact that the article is reporting on:

a. What certain researchers (*x*) have done
b. What yet other researchers (*y*) have said about what these researchers (*x*) have done and what these other researchers (*y*) have done in response.
c. The author's source of information is research articles, which may report on researchers *x*'s research in response to his/her disagreement with the research of researcher *y*.

This makes for extremely embedded clause complexes such as the following:

> [19a]*In another line of argument, [[presented in a paper in Geological magazine,]] Hoffman and Joe Ghiold of Louisiana State University suggest that* [19b]*Raup and Sepkoski's criterion [for identifying a mass extinction] is biased towards periodicity.*

Often there are two nominal groups with embedded clauses or a nominal group and a prepositional group both with embedded clauses joined by a process. For example:

For each stratigraphic stage [[into which the fossil record of the past 250 million years is divided]]	they	determined	the rate of extinction [[defined as the number of families that became extinct in the stage divided by the number of families existing during the stage]].
Prepositional group with embedded clause	pronoun	process	Nominal group with embedded clause

In summary, most embedded material in this Scientific American article serves to add information of a greater degree of specificity to the nominal group than that found in the ranking clause. This was one of two important roles for embedding in Raup and Sepkoski, the other being the packaging of central propositions into facts. There are however very few fact clauses in the Scientific American article. In it (as in Raup and Sepkoski, and the three textbooks - Duff, McGhee, and Trefil and Hazen,) there is some tendency for material imported from other texts to be sited in embedded clauses, and for the author to comment evaluatively in the ranking clause on this embedded material.

4.3.2.3 Passivisation in the Scientific American article

Most verbs in the Scientific American article are active, with only nine verbs in the 1500 word passage being passive. Where the passive is used it does not appear to be the function of the passive to hide the agent, as this is (a) supplied either in the same sentence (3 cases: clauses 2a, 5, 17) or (b) part of well established scientific fact and so the agents are easily understood as the generic 'by geologists', 'by Physicists' etc. (5 cases: clauses 6, 12, 15b 16 clause 40b.) An example of this is [6]'*for each stratigraphic stage into which the fossil record of the past 250 million years **is divided** ...*'). Only in the case of clause 5 is the agent present in object position. In one case use of the passive does conceal the agent ([38]*The proposed mechanisms have been criticised.*) The purpose of this does not appear to be to conceal controversy as witnessed in the process '[38]*have been criticised*', and in the fact that the author is not reluctant to be specific about the parties (Hoffman on the one hand and Raup and Sepkoski on the other) in another part of the controversy elsewhere in the article.

Clause 38 is the only case where the passive process is in a ranking clause. In the other eight cases the passive verb is found in an embedded clause and is describing/ elaborating on the head noun of the nominal group into which the clause is embedded (5 cases: 2a, 5, 6, 12, 40b). In two cases (clause 16 and 18a) the embedded clause is a fact clause. In seven of these eight cases the agent/sayer is not present and focus is on the goal/phenomenon.

This analysis confirms the findings elsewhere in this analysis that the writer has no wish to conceal agency in order, as was found in the research article and textbooks, to promote the impression of objectivity. In fact, as is the way with much journalism, this text attributes ideas and arguments to authoritative human participants for the very purpose of promoting the impression of authorial objectivity.

In summary, because the text is framed as a debate between the human participants, use of the passive in this text is infrequent and, where present, is mainly found in embedded clauses In these it serves not to conceal the agent or pretend that there is unanimity of opinion, but rather it serves textual ends: the goal or phenomenon is what is being foregrounded and these are thus in thematic position within the embedded clause. Use of the passive is equally unusual in both the other popular texts in this study.

4.3.2.4 Conjunctive relations in the Scientific American article

The conjunctive relations in the Scientific American article coincide with the human participants, theme and evaluation (4.3.3.3) in indicating a narrative of conflicting knowledge claims. I begin by mapping out the use of conjunctions in each clause in Table 4.3.9. From this Table, it is clear that there are only two internal conjunctions in this article, both of them serving in pointing to examples. There are many external conjunctions. A large proportion of these are temporal and spatial, as outlined above in the discussion of theme. Temporal and spatial circumstances account for much of the structure of the text. For the most part, these track when research was done and claims made about it, and in some cases where this was published. This supports my contention that this is a narrative not only of research, but also a dialogue of claims arising from that research.

Adversative conjunctions are also common, as expected in a dialogue/debate between opposing interpretations. There are also some causal and conditional conjunctions. The conditional conjunctions play a part in the writer's arguments concerning which researchers are more reasonable in their claims: [46a]**Even if** extinction rate varies randomly,
[50a]**If** it is, [50b]the case for Nemesis and its companion theories weakens.
[25b]**even if** they make it unnecessary to suppose the celestial intrusions have been regular.
Although conjunctive relations in the Time article show many similarities with those in the Scientific American article, adversative conjunctions in Time are rare reflecting the fact that although opposing viewpoints are aired in Time there is no attempt to link these.

As in Raup and Sepkoski and the three textbooks considered, causal relations are usually not realised conjunctively in Scientific American. Rather, they are realised clausally in identifying processes, as can be seen in Table 4.3.2.

In summary, in this article external (real world) conjunctive relations predominate over internal (rhetorical) conjunctive relations. Temporal, spatial and adversative relations tracking claims made about research predominate, confirming this text as a narrative of research and of claims about research. Causal relations are mostly realised clausally rather than conjunctively.

Table 4.3.9: Conjunctive relations in the Scientific American article

Internal conjunctive relations: rhetorical structure	clause	External: real world conjunctive relations	
	1		
	2a	spatial	In the scenario that has received the most attention
	2b		
	2c	spatial	where
	2d		
	3		
	4a		
	4b		
	28		
	29a	Temporal: specific	In 1979
	29b		
	30a		
	30b	Extension: adversative	but
	31		
	32		
	33	Temporal: durative	Since then
	5a		
	6	spatial	For each stratigraphic stage
	7		
	8		
	9		
	34		
	35	spatial	In several scenarios
Elaboration: example	36		for example that
	10		
	11a		
	11b	Extension: adversative	but
	12	Temporal: repetitive Spatial	Every 26 million years At its closest approach to the sun
	13		
	14a		
	14b	Temporal: simultaneous	when
	37a		
	37b		
	38		
Elaboration: example	39		for example
	40a	Clarification: resumptive	As for the Nemesis model
	41	Temporal: punctiliar	Now
	42a	spatial	In a recent paper in Nature
	42b		
	15		
	16		
	17a	Extension: adversative	But
	17b		
	18a	Temporal: immediate	When Hoffman restored the omitted families to the data
	18b		
	43		
	44		
	45		
	19	spatial	In another line of argument
	20		
	21	Extension: variation: replacive	Instead
	22a	Cause: purpose	To analyse the effects of that definition
	22b		
	23a	Temporal: repetitive	For each stage
	23b		
	24		
	46	Conditional: concessive	Even if
	47	Temporal: specific	In the timescale R&S adopted
	48	Causal: general	Hence
	49a		
	49b	Extension: adversative	but
	50	Conditional: positive	If it is

	51		
	52a	Temporal: specific	In their original work
	52b	Extension: addition	and
	53a		
	53b		
	53c	Extension: addition	and
	53d		
	54a	Temporal: durative	Since then
	54b		
	55		
	56		
	25a		
	25b	Conditional: concessive	even if

4.3.2.5 Summary and overview of Mode in the Scientific American article

In this article the marked themes (including textual themes/conjunctions of contrast and circumstances of time and place), combined with nominalisations of mental and verbal processes, function to signal the progression of a narrative of research into the idea of an extraterrestrial cause of mass extinction. By use of marked themes the writer guides the reader very closely in the interpretation of the text enabling the writer to support one of the voices in the debate about research in the article while appearing objective in that s/he is merely reporting what is said. In contrast with Raup and Sepkoski, Duff and McGhee there is little passivisation. Most of the passivisation is in embedded clauses and serves textual ends rather than serving to conceal agency. Both the organisation of the text into a debate and the lack of passivisation to conceal agency confirm that the chosen method of achieving an appearance of objectivity is through attributing ideas and arguments to human participants involved in the debate This is different from the textbooks and research article, which established objectivity through removal of people from the text.

4.3.3 Tenor in the Scientific American article

Tenor refers to the roles of the reader and writer of a text and interaction between them. The Scientific American text is written by a science journalist for an audience of mainly scientists. We therefore do not expect any distancing from science or scientists. In this section I consider the categories of Contact, Affect and Status, Hedging, and Evaluation.

4.3.3.1 Contact, affect and status in the Scientific American article

In this section (cf. 3.2.5, 4 1.3.1 and 4.2.3.1) I consider Contact, affect and status in the Scientific American article, they being three categories which Gerot (1995:104) uses to illuminate the interpersonal metafunction.

Contact in the Scientific American article

The writer shows solidarity with readers (which is what (Gerot 1995:104) means by contact) in that they are expected to find newsworthy and of interest the controversies in fields other than their own. Specifically, the writer expects the reader to be interested in argument over possible models for theories. To the readers the trustworthiness of the methods used in a piece of research are important. The readers are therefore projected as people who show an interest in following the details of research in other fields, and who care about and understand the statistical basis on which the claims in the article were made. The writer is popularising science for a very select and literate group – scientists in other fields. There is some technical language (such as *probability, extinction rate, periodicity, artefact* etc.) likely to be accessible to any scientist There are a fair number of nominalisations, too.

The text is formal to the extent that reader and writer are not mentioned but many researchers and their institutions are mentioned. The text can also be characterised as a narrative of knowledge claims.

A certain amount of scepticism ([1]*notion*, [2a]*scenario*, [2a]*dim, distant companion star* etc) is shown for one of the sides of the argument. However, as the writer supports the other side of the argument we cannot view this as indicating that the writer views science as 'other' in the way that is seen in the Time and Mail and Guardian articles. For the writer and readers, being a scientist is the norm. They are not referred to as scientists, but rather by name or as '[34]*Astronomers and astrophysicists*' and '[40a]*workers*'. The writer projects readers who participate in the values of the scientists whose work is discussed. For example the readers are likely to share the scientists and writers criticism of research that is [19b]*biased* and [20]*not quantitative*.

Solidarity with the readers is also shown in this article through the use of a photograph (see appendix page23). This depicts a crater caused by extraterrestrial impact. It is taken from above, which Kress and van Leeuven (1996:149) view as making it objective. According to them, this is the angle of maximum power for the viewer, as it 'contemplates the world from a god-like point of view'. The photograph illustrates the possibility raised in the article of the possibility of an extraterrestrial object hitting the Earth. It serves as objective proof that such impacts have occurred. This is a real photograph of a real crater that exists on earth. Its truth-value is high. It is real evidence. In terms of the ideational metafunction, this image is analytical with the crater being the carrier possessing various attributes such as size which are enlarged upon in the caption of the photograph.

I would contend that the written text in this article is primary and the photograph elaborates on it. This is because although we may peripherally perceive the photograph before we read and comprehend the first few sentences of the written text, unlike the immediately recognisable *T-rex* in the Mail and Guardian article, the crater is not immediately familiar to us. We do not recognise it for what it is until we examine it closely or even read the caption.

In terms of composition of the article as a whole, the photograph of the crater is at the bottom (Real) and on the left (Given). The photograph represents the Real/earthly, and the written text, which speculates about mass extinction caused by extraterrestrial bodies that cause such craters, represents the Ideal/possible/extraterrestrial. The crater is the Given, the text and its speculations about how such craters were formed, and what the likely result of their formation was, are the New.

Affect in the Scientific American article

Affect refers to 'positive or negative attitude of the writers to the readers and what they are talking about' (Gerot 1995:104) As discussed above in section 4.3.1, the idea of an extraterrestrial cause of periodic mass extinction is treated with irony in the Scientific American article:

[1]*The notion that extraterrestrial forces have regularly and catastrophically intruded into the history of life ...*
[2a]*In the scenario that has received the most attention...* [2a]*a dim distant companion star of the sun ...* [3]*putative star ...proposed mechanisms have been* [38]*criticised...focus of the* [41]*criticism...* [25b]*celestial intrusions.*

Raup and Sepkoski are also represented as using faulty research methods:
[42b]*uncertainties in fossil dating and biases in Raup and Sepkoski's methodology cast doubt on their results ...Raup and Sepkoski* [15b]*pared ... their original data down ...*
The [16]*culling of the data ...Their criterion ... is* [19b]*biased ...criterion not quantitative ... regularity could also be an* [49b]*artefact.*

Interestingly, the statement that [19b]*the criterion is not quantitative* is not hedged, suggesting that the writer agrees with Hoffman and Ghiold's negative assessment of Raup

and Sepkoski's research. In the next clause complex Raup and Sepkoski are represented as having oversimplified in their claim that:
[21]*an episode of mass extinction is simply any local peak in extinction rate*

Although this attitudinal lexis indicates that the writer is against the theory of periodic impact, objectivity is signalled in the journalistic way (rather than the way employed in research articles and textbook), i.e. constructing an argument through quoting the arguments of others, in this case researchers.

The writer represents scientists as sincere and effective in gathering evidence and generating theories (unlike their representation in the Mail and Guardian article) and as ordinary people (like the readers) not as possessing religious/mystical attributes (as in the Time article). In the view of the writer it is possible to develop reliable theories but to do so the evidence, (which must be [20]*quantitative*), must be properly interpreted using the right statistical methods (not [42b]*biased*). By contrast, in the Time article, scientists are portrayed as a group apart from the group formed by writer and readers, although the portrayal of scientists is largely positive (religious authority and intelligence/'geekiness') projecting a readership who views science positively. This scientist group has almost religious authority ([9]*quest,* [3]*like a seer divining entrails,* [58]*Eyes turned heavenward*) on the one hand, but a certain 'geekiness' on the other ([5]*scurry around in the unheated dome,* [18a]*carefully chiselling through the rocks outside Gubbio,* [52a]*intricate statistical gymnastics,* [55b]*advanced radiometric techniques*). In distancing itself from scientists the text employs one of the ideological strategies indicated by Eagleton (1991): that of mystification. This mystification contributes to two powerful myths about scientists: science as authoritative (Lemke 1990) and science as the province of 'geeks' – highly intelligent but eccentric and even socially inept. Both of these myths serve to position science as outside the province of most readers.

Status in the Scientific American article

Status, as I indicated earlier in 4.1.3.1, refers to how the writer includes the reader (Gerot 1995:104). The Scientific American article is impersonal. Self and reader are not referred to at all. At first time of mentioning them, the researchers are referred to by first name, middle initial, surname and the institution they are associated with, signalling their status as an elite group. Thereafter they are referred to by surname only. This is more personal than in research articles which generally refer to researchers by surname only throughout. Through the text, scientists, or those with an interest in science, are included in fields other than their own. The narrative genre is a bid to include the reader. This narrative element is even more marked in the Time article, presumably because readers of this article are not scientists and the writer uses this greater narrative aspect to include them in the text. The article is framed as a narrative of researchers' [6b. 13]hunt or [9]quest for an explanation of what causes mass extinctions. The narrative tone is set right at the beginning of the article:

[1a]In the Evening around the Leuschner Observatory in Lafayette, Calif., a few enterprising rattlesnakes slither out [1b]to toast themselves on the asphalt parking lot

To summarise contact, affect and status, the writer of the Scientific American article projects readers who are scientists and regard science in a positive light. By contrast the Time article projects readers who are positive about science but who are not themselves scientists. Scientists are thus portrayed as 'other', as being slightly 'geeky' but possessing religious authority. The intent of the Scientific American article is inclusive in that the author includes the readers in fields of research other than their own.

4.3.3.2 Hedging in the Scientific American article

Hedges express tentativeness and can either be used to show a writer's lack of commitment to a proposition or a desire not to express commitment (Hyland 1996a: 478). As I discuss below, categorisation of hedges into different types is particularly difficult in the Scientific American text, because it is not always clear what the source of the hedge is – the writer of the article, or the research article from which the information is drawn.

I interpret the hedges marked in the table with an asterisk* in Table 4.3.10 as writer-oriented as I view the writer as hedging content rather than assertiveness. It is not the case that the writer is committed to the truth of the proposition and is merely saying it in an indirect way in order to be polite to readers. Instead the writer views it as a possible model: we could even view these uses as verging into reliability hedges. From this point of view the use of modality in for example:

> [11a]*The companion **would** currently lie at a distance of several light years* ...

reminds the reader that this, as explicitly stated in this case, is a model:

> [10]*...and Richard R Muller of Berkeley proposed models in which ...*

Table 4.3.10 Hedging in the Scientific American article using Hyland's (1996) model

2a	...a dim, distant companion star of the sun **is held** to send...	Writer-oriented hedge: signals lack of writer commitment to p; impersonal claim by uncited others: makes it weaker
4	A reassessment now **suggests** the regular extinctions said to be...	Writer-oriented hedge. Claims that the reassessment suggests it but in fact the writer is also suggesting it
4	... the regular extinctions **said to be** the handiwork of Nemesis may never have taken place	Writer-oriented hedge: signals lack of writer commitment to p; impersonal claim by uncited others: weaker
4	... the regular extinctions said to be the handiwork of Nemesis **may** never have taken place	Reliability: "indicate the writer's confidence in the truth of p / desire to explicitly convey an assessment of the reliability of p"
5	...the isolated event **proposed** by the Berkeley workers...	Writer-oriented
9	Raup and Sepkoski **suggested** that the periodicity reflects a recurrent event,...	Writer-oriented. Writer distances self from p
9	Raup and Sepkoski suggested that the periodicity reflects a recurrent event, **probably** of astronomical origin...	Reliability
10	Daniel P Whitmire ... and ... **proposed** models	Writer-oriented
11a	The companion **would** currently lie ...	*Writer-oriented/reliability
11 b	its orbit **would be** eccentric	*Writer-oriented/reliability
12	star **would pass** through ... the Oort cloud	*Writer-oriented/reliability
12	a region of comets that **is thought** to envelop the solar system	This seems to be a reliability hedge. It assesses the reliability of p. It's not known with certainty but people in general think this.
13	The gravitational influence of Nemesis **would precipitate** a comet shower	*Writer-oriented/reliability
15	Hoffman **points out** that ...	Writer-oriented
16	classified as members of extant groups although they **may represent** morphologically similar...	Reliability hedge: this is represented as a genuine possibility: the content is being hedged
17	small fluctuations in extinction rate ... **would be magnified**	Reliability hedge
19	In another line of argument **presented in a paper in *Geological Magazine***, Hoffman and Joe Ghiold suggest that...	Writer-oriented
	In another line of argument presented in .. *Geological Magazine*, **Hoffman and Joe Ghiold suggest** that...	Writer-oriented

Repeated use of modality in describing these models may serve to keep reminding the reader that what is being said is a model; this is not an accepted idea but this is how for example Richard R Muller's model suggests a companion star might cause periodic extinction.

Hyland (1996:438), following Zadeh (1972), points out that the motivation for a hedge will not always be clear. Hedges make up fuzzy-sets in terms of what the motivation for the hedge is. A fuzzy-set is "a class with unsharp boundaries" in which " the transition from membership to non-membership is gradual rather than abrupt" (Zadeh 1972:4). Although there are "core" hedges where motivation for the hedge is clear (e.g. clearly hedging propositional accuracy or clearly hedging writer commitment), in peripheral cases, it may be unclear whether it is writer commitment or propositional accuracy that is being hedged. Related to this, the analysis in Table 4.3.10 indicates that as well as the motivation for some hedges being fuzzy, the source of the hedge may also be fuzzy. Source and motivation are related; the question is: Who was responsible for this particular hedge? This problem of categorising the source of a hedge is likely to be found in research articles when a fact attributed to another researcher or article is hedged. However in popular articles where most facts have researchers or their articles as sources, the problem is much more common. In hedging, is the writer merely following the lead of the researcher? Crompton (1997) maintains that examples such as these do not constitute hedges. However, it is often not clear who was responsible for hedging. We cannot assume that for example in the following it was the source research article that was responsible for the hedge **may**. After all, the writer of the Scientific American article is not using the source article's exact words, but rather summarising/giving the gist:

> [4a]*A reassessment of the fossil evidence now suggests the regular extinctions said to be the handiwork of Nemesis* ***may never have taken place.***

Had the writer chosen to write:

> A reassessment of the fossil evidence now suggests the regular extinctions said to be the handiwork of Nemesis **never took place**.

the provisional nature of the knowledge is retained in **suggests**. Thus we must assume that use of **may** was a choice made by the writer. If no evidence for a statement is given, Hunston (1994:620) maintains that the default is the writer. I agree with this, as writers of popular articles such as the Scientific American article could choose to do what Fahnestock (1986) found her popular sources did: baldly assert a statement as an unhedged fact, when it had been tentatively stated in the source research article.

Myers (1989:12) argues that use of modality in science research articles does not function to cast doubt on what is said but functions rather as a politeness mechanism. However politeness is not the major function of modality in the Scientific American article where modality combines with bald statement to cast real doubt on the idea of a companion star causing periodic mass extinctions. In science research articles the writers are reporting their own findings. Their audience is (a) researchers working directly in this field and (b) geologists and astronomers not working on this question (Myers' esoteric and exoteric audiences). In Myers' (1989) terms they employ modality to avoid offending other researchers whose own research, or publicly held beliefs, may be cast into doubt by the findings. As Myers (1989:28) points out, this is not the case for a popular science writer. The writer of the Scientific American article is reporting on and to an extent evaluating the work of a number of different researchers whose findings in this case contradict each other. The writer cannot avoid disagreeing with and therefore 'offending' some of them. The difference in audience is a factor here (small audience of researchers in the field plus the broader disciplines of geology/astrophysics in the case of the science research article, versus a much broader range of readers who are largely outside of the disciplines of geology and astronomy in the case of the popular article).

In summary, the analysis above indicates that most hedges in the Scientific American article function to distance the writer from what is being said, and signal to the reader lack of writer commitment to propositional content. Hedging in this article also functions to signal to the reader the correspondence of the proposition to reality. This split between writer-oriented and reliability hedging is also found in the other two popular articles in the study.

4.3.3.3 Evaluation in the Scientific American article

In this section I consider evaluation, a category that includes all meaning that functions to express the writer's opinion and value system, and construct and maintain relations between writer and reader (Thompson and Hunston, 2000:6). I begin in Table 4.3.11 by considering evaluation in each clause in the way suggested by Hunston (1993, 1994) (cf. section 3.2.5.4).

Three main hypotheses are identified in the Scientific American article: the Nemesis hypothesis, N, (companion star causes periodic comet showers); the Alvarez hypothesis,

Table 4.3.11 Evaluation in the Scientific American article

	Activity	Source	Modification	Certainty	value
title	question	writer		N possible	
1	narrate event #	writer	notion, gained wide currency	N possible	+ *current*
2a	project	writer		N unlikely	
2b	hypothesis	writer	scenario, dim, distant, is held	N possible	+ *current* **N hypothesis**
2c	hypothesis	writer			
2d	hypothesis	writer			
3	narrate event #	writer	proposal	N possible	+ *current*
4a	project				
4b	hypothesis	unspecified RA	suggests, said to be may never have taken place	N unlikely	- *accuracy*
28	narrate event #	writer		N possible	
29a	project #				
29b	report finding	Alvarez group	modest claim, reported	probable	+ *accuracy*
30a	state fact	accepted knowledge		known	+ *accuracy*
30b	state fact	accepted knowledge		known	+ *accuracy*
31	state fact	accepted knowledge		known	+ *accuracy*
32a	project				
32b	hypothesis	Alvarez group	proposed, probably	A probable	**A Hypothesis**
33	result	unspecified RAs	finding, apparently, have bolstered the case	A probable	+ *accuracy*
5	narrate event #	Raup & Sepkoski	proposed by	A possible	
6	narrate event #	Raup & Sepkoski		certain	
7	report finding	Raup & Sepkoski		certain	+ *consistent*
8	report finding	Raup & Sepkoski	indicated, weaker	possible	+ *consistent*
9a	project				
9b	hypothesis	Raup & Sepkoski	suggested, probably	R&S possible	**R&S hypoth**
34	narrate event #	writer	possible	R&S possible	+ *useful*
35	hypothesis	unspecified RAs	scenarios	R&S possible	+ *useful*
36a	project				
36b	hypothesis	citation	proposed	R&S possible	+ *useful*
36c	hypothesis	citation		R&S possible	+ *useful*
10	hypothesis	citations	proposed models	R&S possible	+ *useful*
11a	hypothesis	citations	would currently lie	R&S possible	+ *useful*
11b	hypothesis	citations	would be eccentric	R&S possible	+ *useful*
12	hypothesis	citations	would pass through is thought to	R&S possible	+ *useful*
13	hypothesis	citations	would precipitate	R&S possible	+ *useful*
14a	narrate event #	writer		Known	
14b	narrate event #	editor at *Nature*		Known	
37a	report finding	unspecified RAs	support for the notion	R&S probable	+ *consistent*
37b	report finding	unspecified RAs	seem to have occurred	R&S probable	+ *consistent*
38	narrate event #	writer	proposed, criticised	R&S unlikely	- *consistent*
39a	project				
39b	finding	unspecified RAs	appears, not clustered	R&S unlikely	- *consistent*
40a	project				
40b	hypothesis	unspecified workers	argue, would have little chance	R&S unlikely	- *consistent*
41	narrate event #	writer	criticism, apparent	R&S unlikely	- *accuracy*
42a	project				
42b	hypothesis	citation	contends, uncertainties biases, doubt	N unlikely	- *accuracy*

15a	project				
15b	narrate event #	citation *	points out, pared down	Known	- *accuracy*
16	result	citation, writer *	uncertainty, may represent	R&S possible	
17	result	citation, writer	But it also meant, would be magnified	R&S unlikely	- *accuracy*
18a	narrate event #	citation		Known	
18b	result	citation		R&S unlikely	- *consistent*
43	result	citation, writer	highly sensitive	R&S unlikely	- *consistent*
44	assess	citation, writer	equally plausible	R&S unlikely	
45	assess	citation, writer	weakened	R&S unlikely	- *consistent*
19a	project				
19b	assess	citation	suggest, biased	R&S unlikely	- *accuracy*
20	assess	citation, writer	not quantitative	R&S unlikely	- *accuracy*
21	result	citation, writer	Instead, simply	R&S unlikely	- *accuracy*
22a	assess	citation, writer		Known	
22b	narrate event #	citation		Known	
23a	result	citation		Known	
23b	result	citation		Known	
24	result	citation		Known	
46a	result	citation	Even if	Possible	
46b	result	citation		Known	
47	narrate event #	citation		Known	
48a	project				
48b	assess	citation	argues	Probable	
49a	assess	citation, writer	may indeed have been	R&S possible	
49b	assess	citation, writer	could be an artefact	R&S unlikely	- *accuracy*
50a	assess	writer	If	Possible	
50b	assess	writer	case for Nemesis, weakens	R&S unlikely	- *useful*
51	narrate event #	writer		Known	
52a	narrate event #	citation		Known	+ *accuracy*
52b	narrate event #	citation		Known	+ *accuracy*
53a	result	citation		Known	
53b	project				
53c	assess	citation, writer	suggests	R&S probable	+ *accuracy*
53d	assess	citation, writer		R&S probable	+ *accuracy*
54a	narrate event #	citation, writer		Known	
54b	result	citation		Certain	+ *consistent*
55	result	citation	has found	Certain	+ *consistent*
56	narrate event #	writer		Known	
25a	assess	writer	possibility	N,A,R&S possible	
25b	assess	writer	unnecessary	R&S unlikely	- *reasonable*
26a	project				
26b	finding	citation	found	Certain	+ *Consistent*
27	assess	writer	make a powerful case	A certain/ probable	+ *consistent*

* Where a citation occurs in the same sentence, I call this a citation; where a citation occurs in the preceding sentence, and the present sentence (e.g. clause 16) is apparently still citing information from the study mentioned in the preceding sentence, I call the source citation/writer.

\# Clauses which plot the development of research into impact and acceptance of knowledge claims concerning impact.

A, (the mass extinction at the end of the Cretaceous had an extraterrestrial cause); Raup and Sepkoski's hypothesis, R&S, (mass extinctions, periodic at 26 million year intervals, have an extraterrestrial cause).

In terms of certainty, the Nemesis hypothesis is rated possible but unlikely (paragraph 1). In terms of Value, it is viewed as reasonable to the extent that it has wide currency, but ultimately its accuracy or fit to data is questioned. In terms of Certainty, the Alvarez hypothesis (paragraph 2) is rated probable and possible, and in the final paragraph it is rated as close to certain. In terms of Value, the Alvarez hypothesis is rated as accurate (fit to data). Of the three, the Alvarez hypothesis is most consistently viewed in a positive light. In terms of value Raup and Sepkoski's hypothesis is rated possible in paragraph 3, where their research is described, and possible in paragraphs 4 and 5, where studies in support of Raup and Sepkoski are described. Raup and Sepkoski's hypothesis is rated unlikely in paragraph 6, 7, 8, 9, 10 and 11, where criticisms of Raup and Sepkoski's research are found; and it is rated as probable in paragraph 12, in which Raup and Sepkoski's replies to criticism are discussed. Finally in paragraph 13 the writer assesses R&S as unlikely. In terms of Value, Raup and Sepkosi's hypothesis is rated consistent - i.e. a good fit to data (paragraph 3) useful, i.e. - having explicatory power - (paragraph 4 and 5) and consistent - i.e. fit to data - (paragraph 6), but inconsistent - i.e. at odds with the data - (paragraphs 6 and 9), inaccurate - i.e. possibly an artefact - (paragraph 7, 8, 10 and 11), and unreasonable - i.e. poor fit to expectation - (paragraph 13). Thus on the whole, because criticisms of Raup and Sepkoski are given more space than support for them, the reader is left with the impression that, on the scale of certainty, Raup and Sepkoski's hypothesis is unlikely, particularly as this is the writer's final assessment. On the scale of value, the overall impression is that Raup and Sepkoski's hypothesis fits the data poorly, and that their methods were faulty. Overall, the writer of the Scientific American article assesses Raup and Sepkoski's hypothesis in a negative light.

The three popular journal articles are far more dialogic than either the research article or the children's texts, with a marked structure of alternating positive and negative evaluation. The degree of real engagement between two opposing arguments/ pieces of research varies. *The* Scientific American *article* presents the most engaged argument. It argues between the research and knowledge claims of two sets of researchers. A real attempt is made to show via argument that the research with which the writer does not agree is unsupported by evidence. The dialogic structure of the Scientific American article is illustrated in Table 4.3.12.

Table 4.3.12 Alternate negative and positive evaluation of Raup and Sepkoski's hypothesis in the Scientific American article

para	clause	status	value
2	28-33	Finding/hypothesis, Alvarez group, probable	Alvarez hypothesis + accuracy
3	9	Hypothesis, Raup and Sepkoski, possible	**Raup and Sepkoski's hypothesis**
4	34-36	Hypotheses, citations, possible	+ useful
5	10-14	Hypotheses, citations, possible	+ useful
6	37	Finding, unspecified research articles, probable	+ accuracy
6	38-40	Finding, unspecified research articles, unlikely	- consistent
7	41-42	Hypothesis, unspecified research articles, unlikely	- accuracy
8	15-18	Result, citations, unlikely	- accuracy
9	43-45	Result, citations, unlikely	- consistent
10	19-24	Result, citations, unlikely	- accuracy
11	46-50	Result, citations, unlikely/possible	- consistent
12	51-56	Result, citation, probable	+ accurate + consistent
13	25	Assess, writer, unlikely	- reasonable
	26-27	Assess, writer, probable	+ consistent

In paragraphs 4 to 13 the Scientific American article sets up an opposition between evidence indicating periodicity of extinctions, and evidence indicating a lack of evidence of periodicity. Paragraphs 4-6 evaluate Raup and Sepkoski's periodic mass extinction hypothesis positively as possible/probable in status and useful and accurate in value. Then, from part way through paragraph 6, up until paragraph 11 the hypothesis is negatively evaluated as unlikely in status and, in value, inaccurate and inconsistent with other data. In paragraph 12 it is once again positively evaluated as probable (status) and accurate and consistent (value). Finally, in paragraph 13, the writer assesses the hypothesis as unlikely and unreasonable

There is yet another opposition set up in this article: that between the Raup and Sepkioski's periodic mass extinction hypothesis, and the Alvarez single Cretaceous-

Tertiary impact hypothesis. The Alvarez hypothesis is outlined in paragraph 2, where it is positively evaluated as probable in status and accurate in value. It is not mentioned again until the final paragraph, which first of all negatively evaluates Raup and Sepkoski's hypothesis, before finishing by positively rating the Alvarez hypothesis as probable and consistent with other findings.

Both the Time and Mail and Guardian articles also show a clear dialogue/debate structure However, in the Time article there is no real engagement between opposing research. These are merely juxtaposed. Using the narrative of what a particular researcher did, and in what order, the writer describes research findings and knowledge claims. She then goes on to state that a particular researcher disagrees with this research, describes their research findings and claims and then returns to the original narrative of research. So although there is plenty of evaluation there is no interpretation of what all this means. What guidance does the writer give to the reader about which side of the argument can be relied upon? This guidance is not found in argument, but is rather implicit in aspects such as the far greater coverage given to the Impact Hypothesis, and the support for Walter and Luis Alvarez in aspects such as the close-up photograph of them in which they engage the reader with a friendly smile.

In summary, the analysis above indicates that the writer assesses in a negative light Raup and Sepkoski's hypothesis of periodic mass extinction due to an extraterrestrial cause. By contrast, the Alvarez hypothesis, that the Cretaceous mass extinction was caused by an asteroid, is assessed as close to certain. The analysis indicates that like the other two popular texts and unlike all the other texts in the study, the Scientific American article uses sequential positive and negative evaluation to structure the discussion of Raup and Sepkoski's hypothesis as a debate/dialogue. This structure allows the writer to appear objective because the positive and negative evaluations of the hypothesis are presented as emanating from people beside the author. Table 4.3.10 above shows that the source of most clauses is not the writer but rather citations from specified or unspecified research articles.

4.3.3.4 Summary and overview of Tenor in the Scientific American article

The projected readers of the Scientific American text are the exoteric audience who take an interest in scientific findings in fields other than their own (Myers 1989). The writer is an unnamed science journalist, and for both writer and reader being a scientist is the norm so we do not find any distance between reader/writer and scientists. The values of quantitative science – such as that work should be unbiased and quantitative are also the norm for both projected reader and the writer.

In spite of the fact that the reader and writer share the values of research science, the appearance of objectivity is achieved through journalistic means i.e. quoting the ideas of others rather than though the impersonality familiar in research articles and textbooks. This is the reason for the relatively high number of writer-oriented hedges, which signal lack of writer commitment – someone else is responsible for what is said. The other major sort of hedging is reliability hedging (expresses writer's assessment of a statement's reliability). This indicates that solidarity politeness is not the writer's major concern and that the writer does not anticipate that most readers have enough invested in what is said to be offended by it.

The journalistic means of achieving the appearance of objectivity involves framing the article as a debate between researchers. This leads to the structuring of the article by means of sequential positive and negative evaluation of Raup and Sepkoski's thesis. The writer thus uses the researchers as voices in his/her own discussion, gives greater voice to one side of the discussion and in the final paragraph, still apparently objectively, sums up the argument concluding that his/her favoured side of the argument has more merit.

4.3.4 Summary and overview of register in Scientific American.

As mentioned in chapter 2, Halliday (1993:56) describes the scientific register as recognisable because of the effect of "clusters of features". Amongst these, readers may recall, are nominalization of verbs and adjectives, extended nominal groups, a high proportion of relational processes, technical terms, tentative language, causal and reasoning verbs, and impersonal language and passivization. In describing this cluster of features, Halliday uses an extract from Scientific American as an example. However, although most of these features are present in my popular articles in this study, I have found neither impersonal language nor extensive passivisation. The difference is that Halliday's extract is from a long Scientific American article, written by the researchers themselves. By contrast my text from Scientific American is in the initial News section of the journal and is a science journalist's assessment of the research of others rather than a scientist popularising his/her own work. This News section of Scientific American is more like science articles in the press in general, and thus has many similarities to the Time article.

The analysis of register above indicates that this article, like the article in Time, is a narrative of research. It shares values with those of the research article and textbooks in the study, but avoids the research article and textbook method of achieving objectivity and employs a journalistic means of doing so instead. The author of this text is a science journalist and the projected readers are scientists who take an interest in scientific findings in fields other than their own (the 'exoteric audience' (Myers1989)). We therefore neither expect nor find any distancing in the text from scientists or the values of research science. The scientists working on the immediate research question (Myers' exoteric audience) are the authoritative experts upon whose utterances and ideas writer structures his/her argument. They are the central actors in the text, and they give authority to the article. Objectivity is signalled differently in this text than in textbooks and research articles. Instead of using impersonal language to appear objective there are large numbers of human participants in the text, and the writer achieves an appearance of objectivity because s/he is quoting the ideas of others; i.e. objectivity is achieved through journalistic means. Thematic development, verbal processes, nominalised verbal processes, evaluation and circumstance of location in time make this article a narrative of researchers, their research and their conflicting knowledge claims. Through use of verbal processes and through evaluation the text is structured as a debate between rival researchers. The verbal processes make it appear that the researchers are arguing and, combined with the modality used, the writer appears objective. That this is only an appearance of objectivity is indicated in the explicit final statement, the close guidance of reader interpretation afforded by marked themes and the greater voice given to one side of the argument.

The Time article is very similar to the Scientific American article. Both are narratives of research and are structured through sequential positive and negative evaluation. In both the writer uses the voices of researchers to construct the argument/narrative, thus achieving apparent objectivity because s/he is apparently merely reporting on the sayings and work of others. Both articles have a positive attitude to science and scientists, in contrast to the Mail and Guardian article, which I consider in section 4.4. The overwhelming focus on scientists in these two articles, particularly in the Time article, is a major difference from the research article where the people doing the research are suppressed by use of the passive and nominalisation. It also marks a major difference from the textbooks where use of the passive and to some extent nominalisation suppresses people and the facts and ideas are far more important than who proposed them. In the Scientific American and Time articles, thematic development, conjunctive relations and lack of concealment of agency in nominalisations and passives emphasise the narrative nature of the text. This is also aided by the amount of illustration in the Time article, much of which is photographs of the researchers whose ideas are given voice in the article. In the Time article the impression of objectivity and truth is assisted by the many colour photographs, a visual form having the highest truth-value in this cultural context (Kress and van Leeuwen 1996).

The major difference between the Time article and the Scientific American article stems from the difference in readership of the two publications. The projected readers are the broad scientific community in the case of Scientific American and a much broader group in which the readership may include scientists but consists mainly of non-scientists in the case of the Time article. The differences are reflected in Time in a distancing of the reader and writer (assumed to be part of one group) from scientists, who are represented as eccentric and invested with religious authority.

4.3.5 Genre in the Scientific American article

As discussed in section 2.5.1, White (1997) identifies two genres within the media: hard news reporting, and commentary or opinion. The Scientific American and Time texts fall into one of the sub-genres of hard news reporting, the issues report. This sub-genre is grounded in a communicative event and describes the "criticisms, accusations, demands, warnings, discoveries or announcements of some authorised source such as ... a professional expert or scientific researcher" (White 1997:102). This is distinguished from the Mail and Guardian article, which is an opinion piece with frequent interpersonal value judgements about the competence and motivations of scientists.

My analysis of human participants, nominalisation, passivisation hedging and evaluation above indicates how the writer structures his/her opinion of Raup and Sepkoski's work as faulty into a debate between rival researchers. These rival researchers argue the issue out, allowing the writer to appear neutral and objective. That this is an appearance only is reflected in the writer's careful guidance of the readers' interpretation of the text through the use of marked theme. Not only are human participants and their words and thoughts important in this text, but an analysis of nominalisation indicates that researchers words and thoughts take on a life of their own and become nominalised into participants (e.g. [4a]reassessment) in the text.

The text is an exposition. That is it puts forward a particular point of view (Butt et al 1995:17). However, it is disguised as a more neutral genre, the discussion, which presents information and opinions about more than one side of an issue (Butt et al 1995:17). The author is convinced that Raup and Sepkoski are wrong and, in a roundabout way, says so in the first and final paragraphs:

[4a]*A reassessment of the fossil evidence now suggests* [4b]*the regular extinctions said to be the handiwork of Nemesis may never have taken place.*

[25a]*Hoffman's arguments ... make it unnecessary to suppose the celestial intrusions have been regular.*

In the Scientific American article the author looks at the arguments for and against a particular idea and gives the appearance of coming to a 'balanced' compromise, making a judgement of the extent to which the idea is reliable. In brief, the article outlines the 'notion' of an extraterrestrial force intruding on Life. It mentions the background to the theory, before outlining research supporting the theory, research against the theory, a further mitigation of the theory and finally reaches a kind of middle ground between research in favour and against the theory. However, in spite of the appearance of a balanced compromise, the writer's conclusion (extraterrestrial cause for a single mass extinction 65 ma ago, i.e. the Alvarez hypothesis) falls far short of agreeing with Raup and Sepkoski. It agrees with neither their speculation (about the possibility of an extraterrestrial cause of repeated periodic mass extinction) or even their central knowledge claim (of periodicity in mass extinction) The writer of the Scientific American article accepts the Alvarez hypothesis but is prepared to go no further.

In contradiction to Fahnestock's (1986) finding that popular articles are less tentative than research articles, Scientific American is more cautious/conservative than the serious science journal that accepted and published Raup and Sepkoski (1984). In my experience scepticism about new findings as yet unratified as fact by the research community is common in the initial 'News' sections of Scientific American and New Scientist. Raup and Sepkoski (1984) is an article which contains well-supported evidence for periodicity in mass extinction but also contains speculation about the cause of mass of extinction for which it provides no evidence at all. Possibly the greater hesitancy on the part of popular journal authors is a result of the different readership of the popular journal. Because only a small fraction of the readers of Scientific American are researchers in this particular field we can conclude that the majority of readers of Scientific American rely on popular sources for most of their information on areas of research outside their own discipline. The readers of Raup and Sepkoski (1984), on the other hand, have a good chance of being researchers in this field themselves, and are thus very well informed about this area of research and therefore able to make their own judgements. In a serious journal there is a place for (clearly signalled) speculation, even if unsupported by evidence, as this may advance the field by suggesting further directions for research. Myers (1989) also points out that speculation allows researchers to claim precedence for an idea they are working on but for which they as yet have no evidence. Similarly, if Scientific American presents material as well accepted if it is still speculative the journal loses credibility with its readers. The author's way of distinguishing between speculative and accepted material is by distancing him/herself from what is said. Raup and Sepkoski, on the other hand, are not distant from their research. They distinguish speculative material by hedging it.

4.3.6 Ideology in popular science articles

The underlying assumption of the Scientific American article is that scientific research, and the controversies between researchers, are news. White's (1997:104) identification of three categories of subject matter in news reports - aberrant damage, power relations, normative breach - is of value here. Elements of two of these categories are identifiable in the popular science articles in my study: power relations and aberrant damage. The power relations reported on in science news are that new findings or hypotheses challenge the existing ones, eliciting responses from those that support the existing hypotheses and theories. The Time and Scientific American articles both focus on the discoveries of scientific researchers, and particularly in Scientific American, on their criticisms of rival researchers. The news in the Scientific American article is that Raup and Sepkoski have challenged the work of other researchers by suggesting periodicity of mass extinctions as a result of an extraterrestrial body. The article reports on a rival researcher (Hoffman) who, according to the article, demonstrates the faulty nature of Raup and Sepkoski's methods and findings.

In section 2.3.3.5 I mentioned Latour and Woolgar's (1979) discussion of the role of "inscription devices" in providing graphical evidence of measurements taken by a machine – i.e. evidence is at several removes from what is being proved. Similarly Pinch (1985:6) describes a case where "splodges" on a graph are taken as evidence of one substance (Ar^{37}), which in turn is taken as evidence of another phenomenon (solar neutrinos). Once again, proof is only provided indirectly at several removes from what is being measured. At each step the final results can be challenged by challenging the assumptions and observations involved in the intermediate steps.

A similar case can be seen in the Raup and Sepkoski article described in chapter 4 1 In this article, statistical counts of families of fossils are evidence and reflection of the cause and time-frame of mass extinction 65 million years ago, which can of course not be measured/observed directly but only as it is reflected in chemical, stratigraphic or fossil evidence. The Scientific American article reports how Raup and Sepkoski's use of the indirect measure (fossils) is challenged by Hoffman, who criticises Raup and Sepkoski's findings on several grounds including uncertainties in fossil dating, and how they manipulated their statistics. It is interesting that of the popular articles examined in this study, it is the one whose readership is scientists that regards as news the evidential challenges to particular findings. In White's terms (1997) this article is reporting on challenges or threats to power relations. If Hoffman's challenge to Raup and Sepkoski is sustained this means a loss in prestige for Raup and Sepkoski. In the Time article by contrast what is news is partly the whole idea of an extraterrestrial cause of mass extinction.

A wider question is why do some areas of research get reported in the popular press and others do not? As the Scientific American article points out, this area of research received much attention in the popular press. This is partly because of the past aberrant damage that occurred during the impact of a meteorite, as well as the possibility of future aberrant damage should a meteorite ever hit earth again. The idea of an extraterrestrial cause of mass extinction is threatening to us. The possibility that it might happen is unpredictable and uncontrollable. That it has some power in the popular imagination is evidenced by the fact that it has been the subject of disaster movies such as *Meteor* and *Deep Impact*. This is the focus on disaster, or what is life-endangering to humans, which Ungerer (1997:314) says serves to make news stories emotionally relevant and news-worthy. There is also our fascination with dinosaurs, firstly because they are monsters, and also because their position often mentioned (in popular articles) as 'rulers of the earth' is similar to our own. Their rule proved precarious, and ours could be precarious too.

In the research article and textbooks in this study the appearance of objectivity was important and this was achieved through the removal of people by omission, nominalisation and passivisation. Objectivity is encouraged by journalism textbooks, but my analysis indicates that in contrast to the research article and textbooks in the study, neither the Scientific American nor the Time article establish objectivity by removing people. Instead, attribution of ideas and arguments to others is one means by which journalists establish objectivity, so that it appears that the human participants in the article are arguing and the writer is neutrally reporting the argument. The writer never speaks with his/her own voice but instead skilfully structures the text as a debate through sequential positive and negative evaluation.

In chapters 4.1 and 4.2 I outlined power relations within research articles and textbooks. In discussing power relations in the texts in this study, it is necessary to distinguish the writer, the reader and two groups within the scientific community: those working on the immediate research question and those in other fields who take an interest in the findings. There may be overlap between these; for example in research article, the writer is a member of the group working on the immediate research question, and the readers fit into one or other of the scientist groups. Briefly, as Myers (1989) has shown, writers of research articles are less powerful than the readers, who represent the research community. The research community is much more powerful than individual scientists, who must show deference to the discourse community. Writers of research articles must take account of two audiences: other researchers working on the present research problem, and the wider scientific community who show an interest in the findings. Writers of research articles increase their chances of their propositions being accepted by the scientific community and thus achieving the authority of factual status if they present what them impersonally, following the conventions for objectivity. By contrast with research articles, writers of textbooks summarise propositions in the field that have been accepted by the research community and that thus do currently have the authority of factual status. Writers of textbooks are 'speaking for' the powerful scientific community, and they are thus more powerful than their readers, who are relative neophytes.

In popular articles power relations can involve a number of possible configurations of reader, writer and scientific community. The researcher who popularises his/her own work for the rest of the scientific community (e.g. long articles in Scientific American) must still take account of both groups in the scientific community, and shows deference to members of the community active in the research question (Garcés-Conejos and Sánchez-Macarro, 1998). In popular science news articles the writer is usually a science journalist. The readers may be scientists (that part of the scientific community that takes an interest in the findings but is not active in this particular area of research e.g. the Scientific American article). Alternatively the readers may be non-scientists (e.g. the Time article in the study). In both of these cases the writer scaffolds his/her argument on the ideas and utterances of the section of the scientific community involved in the immediate research problem. The writer does this to give the impression of objectivity and to give what is said authority. This group are the central participants in popular science articles, being the authoritative source that is essential to the credibility and impression of credibility created by journalists. The writer does not however show deference to the scientific community in the sense of hedging disagreement with them, as is found in research articles. Instead the writer is eager to show controversy, as within the values of journalism, this is interesting, and also indicates that they have consulted a number of authoritative sources and are giving 'both sides' of the 'story'.

In contrast to the Mail and Guardian article, both the Scientific American and Time articles are positive towards science and scientists. The writer of the Scientific American text is writing for readers who are projected as scientists. There is thus no distancing in the text from science or scientists. Both are viewed in a positive light. By contrast, although the writer and reader of the Time article view science and scientists in a positive light, neither reader nor writer is identified as a scientist. The writer views herself and the readers as part of the same group and scientists as a separate group apart, highly intelligent, invested with religious authority, but also eccentric.

4.3.7 Summary

In this sub-chapter I have characterised popular science articles as having some similarities with textbooks and research articles at the level of register. The greatest difference at this level is that, unlike the other two genres, popular articles do not remove people from the account but instead populate the account with large numbers of human participants. In genre of popular science is journalism. The Time and Scientific American articles are issues reports (White 1997), describing the new discoveries and opinion differences of researchers. Popular science is often a narrative of research, and in the case on the two articles reported on in this chapter (the Scientific American and Time articles), a narrative of rival knowledge claims. At the level of ideology I have claimed that the Time and Scientific American articles report on power relations to the extent that new findings challenge the status quo. In contrast to textbooks and research articles popular science articles achieve objectivity by attributing information to researchers rather than by making the account impersonal. The writer of popular accounts reports new ideas (i.e. have not yet been accepted as fact by the research community) but distances him/herself from these ideas. By contrast the research article reports new ideas but does not distance him/herself from them and in fact tries to represent them as much as possible (while still avoiding challenge by the reader) as if they were already accepted as fact by the research community. The textbook confines itself almost entirely to accepted facts. In the next section (4.4) I turn my attention to a popular text from the Mail and Guardian that, unusually in this study, has little concern with appearing objective.

4.4 The Mail and Guardian: An extract from a newspaper article

4.4.0 Introduction

In chapter 4.3 I reported on my analysis of an article from the Scientific American, and referred to a similar article from Time. In this chapter I analyse another popular science article, but one that differs from the other two in both genre and ideology, and has some differences at the level of register. Both the Scientific American, and Time articles are examples of issues reports, a genre that describes the "criticisms ...or discoveries ... of some authorised source such as ... a professional expert or scientific researcher" (White 1997.102). The Mail and Guardian article, by contrast, is an example of an opinion piece, a genre in which we expect a greater incidence of interpersonal value judgements. Moreover, in contrast to the Scientific American and Time articles, which have a positive attitude towards science and scientists, my analysis below indicates that the Mail and Guardian article has a negative attitude towards science and scientists. I begin with an examination of register, under the categories of Field (4.4.1), Mode (4.4.2) and Tenor (4.4.3). I then move on to consider Genre (4.4.5) and Ideology (4.4.6). The reader can consult a copy of the original text of the article by folding out page 35 of the appendix.

4.4.1 Field in the Mail and Guardian article

In this section I consider who the human and other participants in the text are and what processes these participants enter into. I consider also the circumstances in the text.

4.4.1.1 Human participants in the Mail and Guardian article

I begin this analysis with Table 4.4.1, which lists all human participants and considers, firstly, whether they are major participants or part of circumstances (minor participants), and, secondly, whether they are specific people or generic representatives of a group.

Table 4.4.1: Human Participants in the Mail and Guardian article

		major/minor; generic/specific
1b	those who don't see it as another source of trivialisation of their subject	Major, generic
6	we (writer, reader and people in general)	Major, generic
8b	you (people in general)	Major, generic
10a	Most right-thinking palaeontologists	Major, generic
11	they (most right-thinking palaeontologists)	Major, generic
12	Academics	Major, generic
13	those who insist there is only one explanation	Major, generic
16	humans	Minor, generic

Almost all the human participants in this text (as Table 4.4.1 reveals) play major roles, but interestingly, all are generic. This means that, unlike in Time or the Scientific American article, the ideas and theories are not attributed to real existing researchers, but rather to a faceless group of academics and palaeontologists. We have only the writer's word for it that the opinions and theories attributed to these academics and palaeontologists are in fact held by any real scientists.

In contrast to the other two popular texts, the Mail and Guardian article is peopled with the reader and writer (you and we) and an unsympathetic generic group of scientists. The reader and writer are included in the text in: [6]*since then **we have had** death by genetic changes*... and [8b]*That ought to have sorted the big oafs out, **you would think**.* Academics and palaeontologists are included via disparaging remarks such as that they would "*naturally prefer*" their own simple explanation with the implication of "[10a]*most right-thinking palaeontologists*" being that some of them are wrong-thinking. This indicates that the readership of the newspaper is projected as being '*you*' and '*we*': non-scientists who view science with suspicion.

4.4.1.2 Processes, participants and circumstances in the Mail and Guardian

This section will consider the kinds of meanings realised in this text, concentrating on material processes, fact clauses, and mental processes. I begin this account by listing the participants, processes and circumstances in the text in Table 4.4.2:

Table 4.4.2: Processes and participants in the Mail and Guardian extract

	Actor	Material	Goal	Circumstances
3a	a week	goes by		without some new theory
3b	some new theory for zapping the dinosaurs	hitting	the headlines.	
5a	these	could have blotted out	the sun's light	By throwing ...dust into the atmosphere
5b		killing	vegetation	
5c		trashing	the food chain.	
8a	That	ought to have sorted out	the big oafs	
10c		to knock	T-rex	off his perch.
18a		been	there	
18b		survived	that	
19	the incredibly rare event of ...	could do in	the dinosaurs	
	Senser	**Mental**	**Phenomenon**	
8b	you	would think	FACT (That ought to have sorted the big oafs out)	
10a	Most right-thinking palaeontologists	do not believe	FACT (that even this ... impact was enough, ... to knock T-rex off his perch)	today
11	they	subscribe to	the theory of death by all of the above:	
12	Academics	would prefer	FACT (that the explanation ...were simple.)	
16	dinosaurs	had seen	it all.	During that time
17			Climatic upheaval, ... meteor impacts?	
		Existential	**Existent**	
13	there	are	those who insist there is ... one explanation	
14	there	is	one last... fact .. in the way of ...	
	identifier	**intensive**	**identified**	
1a	Discovering the fate of dinosaurs	is	the hot topic	in palaeontology right now
1b	it	is		among those who...
2	The fact that no ...way has been found to ...	is	the most telling tribute science has yet paid them.	
4	it*	was	death by volcanic eruption.	A few years back
15	Dinosaurs	were	the dominant life form	on this planet for 160 million years
	Carrier	**possessive**	**attribute**	
6	we	have had	death by genetic changes...	Since then
	Carrier	**intensive**	**attribute**	
10b	this monumental impact	was	enough,	by itself,

Table 4.4.3 reflects a count of the number of processes of each type in the text, including those in embedded clauses.

Table 4.4.3: Summary of processes in the Mail and Guardian text

	Material	mental	existential	identifying	attributive	
Ranking clauses	10 (41%)	5 (21%)	2	5 (21%)	2	24
Embedded clauses	7	1				8

Material processes, as revealed above are the most numerous in both ranking and embedded clauses in this text, and they invariably realise meanings in the real physical world to do with killing the dinosaurs or effects on the environment of a meteorite impact.

As in other texts, ideas are embedded in fact clauses but unusually they are also located in material and relational clauses. There are three fact clauses in the extract, and in two cases these are attributed to a generic group of scientists/academics:

10a*Most right-thinking palaeontologists do not believe* 10b*that even this impact was enough to knock T-rex off his perch*;

12*Academics would prefer that the explanation of the extinction ... were simple.*

In a third case a fact clause is attributed to the reader/people in general:

8a*That should have sorted the big oafs out* 8b*you would think.*

An interesting contrast with the Time article, where fact clauses were the major vehicle for the explanation of theories, is that theories in this extract are associated with three different processes:

1. **There is an identifying process**:

4*A few years back, it (theory)* ***was*** *death by volcanic eruption.*

2. **There are material processes:**

5a*By throwing huge amounts of dust into the atmosphere, these* ***could have blotted out*** *the sun's light,* 5b***killing*** *vegetation* 5c*and thus* ***trashing*** *the food chain.*

3. **And there is an attributive process.**

6*Since then we* ***have had*** *death by genetic changes, death by continental break-up, and, most famously, death by meteor impact.* 7*An impact between ...*

An identifying process with a material process that elaborates on it is an expected way of conveying the abstract ideas constituted in the theories of dinosaur extinction. The attribution of these theories to 'we' (i.e. the reader and writer) is more surprising. It is almost as if these theories are something 'we' have had to put up with.

Interestingly, there are five ranking mental processes, with the sensers in three of the cases being academics and palaeontologists. Through these we are afforded a very broad and, in contrast with Time and the Scientific American article, unsympathetic impression of what theory these academics and palaeontologists favour:

They [10a]*do not believe that impact was enough*

They [11]*subscribe to the theory of death by all of the above*

They [12]*would prefer that the explanation were simple*

Unlike the situation in the Time and the Scientific American articles, the writer is not really interested in the details of the theories themselves. A very broad outline is given.

There are no verbal processes. Unlike the Scientific American and Time articles, no one is interviewed or quoted. The source of none of the information is provided. No necessity is felt by the author to back up his case by quoting experts or his source. We are afforded a cynical look into the workings of the minds of academics and palaeontologists, but they do not speak for themselves.

As Table 4.4.3 indicates, this text focuses on 'we' the reader and writer and our expectations and experience of the theories of palaeontologists. Secondly, the extract is also about theories of what killed the dinosaurs, and a large proportion of the participants in the text deal with this. Theory is explicitly opposed to fact in this extract ([14]*But there is one last, humungous fact standing in the way of all one shot kills all theories*)

The theories and events surrounding them are often expressed in a humorous or informal way:

Humorous: [2]*sure-fire way*; [2]*to get rid of dinosaurs;* [3b] *theory for zapping the dinosaurs;* [6]*death by genetic changes, death by continental break-up, and, most famously, death by meteor impact.* (Reminiscent of a murder mystery); [7] *a very big rock and a hard place* [11] *the theory of death by all of the above: a multiple-whammy of volcanic eruptions ...* [11]*with a meteor-impact chaser:* [14]*all one shot kills all theories.*

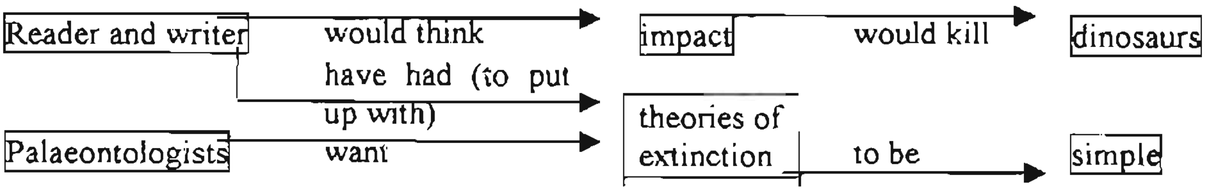
Informal: [5c]*and thus trashing the food chain*; [19]*incredibly rare event*

The almost ridiculous nature of these theories reflects the writer's idea of the topic of dinosaurs as boring and overworked. Dinosaurs are mentioned flippantly, and usually in association with how they died:

[1a]*fate of the dinosaurs;* [2]*get rid of the dinosaurs;* [3b]*zapping the dinosaurs;* [8a]*sorted the big oafs out;* [10c]*to knock T-rex off his perch;* [12]*extinction of the dinosaurs;* [15]*Dinosaurs were the dominant life form;* [16]*dinosaurs had seen it all.*

The writer and the reader – with whom the article sympathises - have their expectations disappointed. They might reasonably expect that impact would have caused the extinction of the dinosaurs, but that turns out not to be the case. The writer and reader have also had to put up with some tiresome behaviour from palaeontologists and academics, who have put forward one far-fetched theory after another in quick succession. Palaeontologists and academics are a querulous and self-serving group, some of whom are '[10a]*right-thinking*', but others of whom [13]*insist on their own explanations*. The choice between theories among these palaeontologists and academics is not based on objectivity, but rather on what they [12]*prefer* or [11]*subscribe to*. Table 4.4.4 shows meanings construed in the Mail and Guardian extract in simplified form.

Table 4.4.4 Meanings construed in the Mail and Guardian extract



Circumstances

The circumstances in the extract refer to the field of Palaeontology, both place (bold) and present time (underlined). This indicates that the present is the main focus of the text. There are also two circumstances to do with the remote time of the dinosaurs:

[10a]*Most palaeontologists today*
[1a]***In palaeontology** right now*
[4]*A few years back it was death by volcanic eruption*
[6]*Since then we have had death by genetic changes*
[16]*During that time dinosaurs had seen it all*
[15]*Dinosaurs were the dominant form of life **on this planet** for 160 million years*

Table 4.4.5 Circumstances in the Mail and Guardian article

Duration	Place	Time	Manner	Accompaniment	Total
4 (33%)	4 (33%)	2 (17%)	1	2 (17%)	12

4.4.1.3 Summary and overview of Field in the Mail and Guardian article

The Mail and Guardian article focuses on two main areas: "*we*" the reader and writer and our experience of the theories of palaeontologists, and secondly it focuses on theories of what killed the dinosaurs. "*We*", the reader and writer, have had various far-fetched theories foisted on us by scientists, a subjective group who are led by their own preferences. A generic faceless group (unlike the other two popular texts), scientists are associated with mental processes (they have thoughts and ideas ascribed to them) but they are not associated with verbal processes and thus never speak for themselves. Most processes in the text are material processes and these congruently encode real physical meanings to do with the death of the dinosaurs and effects on the climate. In field (but, as will become clear from my analysis below, not in tenor) the text is most like the other two texts for non-scientists – the texts for children and the Trefil and Hazen text.

4.4.2 Mode in the Mail and Guardian article

As in previous analyses of this kind I look below at ways in which the writer of this text has chosen to organise the message. Besides examining theme, nominalisation, embedding, passivisation and conjunctive relations as I do in other texts in the study, I also consider ellipsis of clauses in the article, as this is of particular interest in this text.

4.4.2.1 Theme in the Mail and Guardian article

Table 4.4.6 provides a clause by clause analysis of theme in the Mail and Guardian article. In the fourth column of the table I signal the markedness of themes using Gosden's (1992) categories.

The Mail and Guardian text is clausally simple, with many of the clause complexes consisting of a single clause (only six out of nineteen clause complexes have more than 1 clause). This, as Halliday (1989) has noted, is usual for written texts.

There are a large number of marked themes in this article: 'heavy' themes, adjuncts of location in time, and textual themes indicating contrast. These themes confirm that the writer's chosen method of textual development is to set up certain expectations in the reader and then indicate that these expectations are false. The writer sets up expectations in clause 1-8 and then indicates these expectations are false in clause 9 We have a pattern of:

Clause 1 & 2: maintenance of theme

Clause 4-6: marked theme - expectation

Clause 9: Textual theme indicating contrast - between expectation and reality

Similarly, the writer sets up expectation in clauses 10-13 (maintenance of theme), and then indicates these expectations are false in clause 14. The themes of clauses 15-19 are heavy themes signalling the writer's interpretation of the true state of affairs.

Table 4.4.6 Theme in the Mail and Guardian article

	Textual	Interpersonal	Topical theme	Markedness
1a			Discovering the fate of dinosaurs	
1b	at least,		it	
2			The fact ((that no single, sure-fire way has been found to get rid of dinosaurs))	Heavy theme
3		Hardly	a week	interpersonal
4			A few years back,	Location in time
5a			By throwing huge amounts of dust into the atmosphere,	manner
5c	and thus			Cause: result
6			Since then	Location in time
8a			That [impact]	
8b			you	
9	But		no	contrast
10a			Most right-thinking palaeontologists today	
10b	that	even	this monumental impact	interpersonal
11	Instead,		they	contrast
12			Academics	
13	Indeed,		there	Elaboration: verifactive
14	But		there	contrast
15			Dinosaurs	
16			During that time (- 40 times longer than anything approaching humans have been around -)	Heavy theme
17			Climatic upheaval, shifting continents, volcanic eruptions, meteor impacts?	Heavy theme
18				
19		Only	the incredibly rare event (of several global catastrophes striking all at the same time)	Interpersonal Heavy theme

Nominalisation: italics; **clause as theme: bold**; marked theme: underlined

4.4.2.2 Embedding and nominalisation in the Mail and Guardian article

In this section I consider embedding and nominalisation in the Mail and Guardian article.

Embedding

Embedded material in this Mail and Guardian article serves two functions. Firstly, most embedding adds to the specificity of what is said in the ranking clauses (a feature found in Raup and Sepkoski, Trefil and Hazen and the Scientific American article). Secondly, some evaluative comment is situated in the embedded clauses. This feature is also found in the Time article.

1. **Embedding that adds to the specificity of what is said in the ranking clauses:**

[3]*Hardly a week goes by without some new theory [for zapping the dinosaurs] hitting the headlines.*
[16]*During that time [- 40 times longer than anything approaching humans have been around -] dinosaurs had seen it all.*

2. **Embedded clauses as a site of evaluative comment (underlined)**

[1a]*Discovering the fate of dinosaurs is the hot topic in palaeontology right now –* [1b]*at least, it is among those [[who don't see it as another source of trivialisation of their subject.]]*
[13]*Indeed, there are those who insist there is only one explanation [(namely their own).]*
[14]*But there is one last, humungous fact [[standing in the way of all one shot kills all theories.]]*

Nominalisation

There is not much nominalisation in this extract – only six different nominalisations in a 327 word extract: [1b]*trivialisation,* [4,6,]*death,* [4]*eruption,* [6]*changes,* [6]*break-up,* [6,7,10b]*impact* [12, 13]*explanation,* [12]*extinction.*

1. **Some of the nominalisation serves to show cause and effect and to keep the reasoning within the same clause:**

[4]*A few years back, it (the new theory) was death by volcanic eruption.* [A few years back the theory was that volcanoes erupted and caused the dinosaurs' death {to die}].
[6]*Since then we have had death by genetic changes, death by continental break-up, and most famously, death by meteor impact.*

This also allows "death by" to be foregrounded and comically reiterated – comic in that it is reminiscent of the murder mystery.

2. **An example of nominalisation for the purpose of encapsulation (Thompson 1996:17) or distillation (Martin 1993:267) of a technical term is:**

[12]*Academics would naturally prefer that the explanation of the extinction of the dinosaurs were simple.* [...the explanation of what made the dinosaurs extinct were simple.]

The nominalisation is less clumsy than the more congruent meaning.

3. **Another instance of nominalisation is:**

[12]*Academics would naturally prefer that the explanation of the extinction of the dinosaurs were simple.* (whose explanation?)

This is a case of a nominalisation being placed in relation to an evaluative attribute, 'simple'. Also, the subject and finite are removed, making 'the explanation of the extinction of the dinosaurs' into a general truth/theory. However, this move towards a general truth is undermined in two ways: firstly by the hedge 'Academics would naturally prefer ...'. This indicates that in fact the explanation is actually not simple. Secondly, the move towards making the 'the explanation of the extinction of the dinosaurs' into a general truth is undermined in the next sentence where the subject (who explains?), which has been removed in nominalising the explanation, is deliberately made explicit:

[13]*Indeed, there are those who insist there is only one explanation (namely their own).*

This humorously undercuts the apparent wish of 'some academics' to have their own explanation accepted as the only one.

4. **A third instance of grammatical metaphor is the use of interpersonal metaphor in:**

[1a]*Discovering the fate of dinosaurs is the hot topic in palaeontology right now – [1b]at least, it is among those who don't see it as another source of trivialisation of their subject.*

This assumes that it is a fact that people are trivialising palaeontology. In this way the writer evaluates palaeontology as trivial but does not need to say whose evaluation this is. This is one among many instances of the writer's negative evaluation of the field.

In short, most nominalisation in this text serves to show cause and effect and to keep the reasoning within the same clause. Another function is to avoid mention of agency, allowing the writer to negatively evaluate the field ([1b]*trivialisation*). In yet another case the writer avoids mention of agency by use of nominalisation to comment negatively and comically on scientists in the next sentence ([12]*explanation*).

4.4.2.3 Passivisation in the Mail and Guardian article

There is only one passive process in this text:

[2]*The fact [[that no single, sure-fire way has been found to get rid of dinosaurs]] is perhaps the most telling tribute science has yet paid them.*

This is the same as the use of passives in the Scientific American article. Firstly, it is in an embedded fact clause; secondly, the agent is omitted but the implied agent is the generic 'by scientists' or 'by science'; and, thirdly, the purpose of passivisation appears to be textual: the focus is on the goal ('[2]*sure-fire way*') rather than the agent.

The fact that almost all processes are active is perhaps in line with the idea that active constructions are more interesting and engaging than passive constructions. Another interesting method of omitting the agent is used in this extract: use of non-finite processes or omitting both agent and process all together. The purpose of this does not appear to obscure who the agent is, because in all cases the agent is recoverable from context, having been mentioned in the preceding clause. Instead, I suggest that these agentless and non-finite processes help create the informality of the text and its humorous, jocular tone:

[7a]*An impact between a very big rock and a hard place at something like 96 000kph.*
[9]*But no.*
[17]*Climatic upheaval, shifting continents, volcanic eruptions meteor impacts?*
[18a]*Been there,* [18b]*survived that.*

4.4.2.4 Conjunctive relations in the Mail and Guardian article

The use of conjunctions in each clause in the Mail and Guardian article is mapped in Table 4.3.7. On the evidence of this Table, external conjunctive relations predominate in the Mail and Guardian text. As in the Time article, reasoning is realised in mental processes rather than being conjunctive or being realised in identifying processes as was the case in Raup and Sepkoski and the textbooks. The conjunctive relations are mostly temporal (related to the fact that the author is narrating the development of theories), or else they are elaborative or extending. The elaborative and extending conjunctions are corrective, adversative, replacive, verifactive and adversitive, most of which indicate that the real state of affairs is different from what was expected.

Table 4.4.7 Conjunctive relations in the Mail and Guardian article

Internal conjunctive relations: relations within the text itself	clause	External conjunctive relations (between events in the real world)	
	1a		
elaboration: corrective	1b		at least
	2		
	3		
	4	temporal: specific	A few years back
	5a		
	5b		
	5c	causal	and thus
	6	temporal: following	Since then
	7		
	8a		
	8b		
	9	extension: adversative	But
	10a		
	10b		
	10c		
	11	extension: replacive	Instead
	12		
elaboration:verifactive	13		Indeed
	14	extension: adversative	But
	15		
	16	temporal: durative	During that time
	17		
	18a		
	18b		
	19		

4.4.2.5 Ellipsis in the Mail and Guardian article.

There is considerable clausal ellipsis in this short extract. This ellipsis gives the extract a cryptic/conversational feel and contributes to its informality:

[8a]*That ought to have sorted the big oafs out,* [8b]*you would think.* [9]*But no.* (it didn't)
^E:c

[7]*An impact between a very big rock and a hard place at something like 96 000kph,*
^E:c (This was ...)
[7]*unleashing the violence of 10-million hydrogen bombs.*

...dinosaurs had seen it all. [17]*Climatic upheaval, shifting continents, volcanic eruptions meteor impacts?* ^E:c (They had seen...)

[18a]*Been there,* [18b]*survived that.* (Dinosaurs had... and they had...)
^E:c ^E:c

4.4.2.6 Summary and overview of Mode in the Mail and Guardian article

The organisation of the Mail and Guardian text, and its use of theme, conjunction, nominalisation and ellipsis, are all a reflection of the humorous intention of the text. Thematic development sets up the (often obviously false) expectation of a particular theory of dinosaur extinction and this is then undercut in the last line of each paragraph through the use of adversative conjunctions.

Almost all constructions in the text are active, perhaps because in journalism active constructions are regarded as more engaging of reader attention. Instead, to omit (although not conceal) the agent, non-finite clauses are used involving clausal ellipsis that omits both agent and process. These devices are part of what creates the informal, jocular tone of the text. The writer also uses nominalisation to avoid mentioning agency and commenting negatively on scientists and palaeontology as a field.

The result of all these organisational devices is that the writer is repeatedly able to make a statement and then correct it or point out that it is wrong in the next clause:

[1a]*Discovering the fate of dinosaurs is the hot topic in palaeontology right now –* [1b]*at least, it is among those who don't see it as another source of trivialisation of their subject.*

[8a]*That ought to have sorted the big oafs out,* [8b]*you would think.* [9]*But no.*

[13]*Indeed, there are those who insist there is only one explanation (namely their own).*

[14]*But there is one last, humungous fact standing in the way of all one shot kills all theories.*

[17]*Climatic upheaval, shifting continents, volcanic eruptions meteor impacts?* [18a]*Been there,* [18b]*survived that.*

In this way the writer sets up what are assumed to be our (the readers') expectations/ assumptions and then indicates them to be wrong So the reader has his/her assumed common-sense ideas contradicted in the article.

4.4.3 Tenor in the Mail and Guardian article.

Tenor, as mentioned previously, refers to the relationship between reader and writer and how the subject matter is regarded. Because the diagrams in this article function in constructing interpersonal meaning to a greater extent than in the other texts considered so far, I consider them as a category of Tenor in section 4.4.3.1. Here I also consider the categories of Contact, Affect and Status, Hedging, and Evaluation.

4.4.3.1 Illustrations in the Mail and Guardian article.

The Mail and Guardian article has two photographs (see appendix page 35). One is a scene from the BBC's Walking with Dinosaurs, which was showing on TV at the time that the article was published; the other is a photograph of what is apparently a realistic model of a T-rex. Because the image of T-rex is so well known, we probably notice the T-rex first, and know the article is about dinosaurs before even reading the headline, even if we do not look directly at the T-rex but notice it only peripherally. Thus the images are primary in this article, and the text elaborates the images. I now consider each of the two images in turn:

The *Liopleurodon* from 'Walking with dinosaurs'

This is a framed photograph of a swimming *Liopleurodon*. The viewer is positioned on the sea bed and is thus brought into the *Liopleurodon*'s environment. We see the *Liopleurodon* from beneath, giving the impression of menace and size. Perspective is important in creating the sense of threat and menace in this photograph. The *Liopleurodon* is represented as being high above us (more powerful than we are), swimming out of the picture. Its tail is blurred giving an impression that it is far away from the head, which is in focus. This gives the impression of great size. We do not see the 'face' of the *Liopleurodon* - just the underneath of its body, including very threatening-looking teeth. Although we are positioned on the seabed and have thus been drawn into the *Liopleurodon*'s environment, the animal does not see us – we see it. So in this case we must see this picture of *Liopleurodon* as an offer of information (Kress and van Leeuven 1996:129). The *Liopleurodon* and its seabed surroundings are objects of interest that we can observe.

The image is a black and white photograph of a living animal that has actually been extinct for a long time. So the image presents itself as real, but actually it is not real. Even the seascape shows long extinct plants. The background is hazy and out of focus – as it would be if we were to see something under the sea – so once again the image is presenting itself as real. The perspective also adds to the impression that the image is real, as the photograph gives an impression of depth as if the *liopleurodon* is swimming towards the viewer. A fair amount of detail is shown – about as much as we would see in a photograph taken under water. Overall, the image presents itself as highly credible: we view it as the photograph of a real living animal.

Photograph of *T-rex*

Like the *Liopleurodon*, the *T-rex* is both actor and vector realising the non-transactional action of roaring/baring its teeth/menacing the unseen goal. We, the viewers, are the goal.

The *T-rex* is not framed. It has escaped from its frame and jumped out onto the page. Unlike the *Liopleurodon*, into whose environment we have been drawn, the *T-rex* has invaded our environment and is eating the words on the page. The *T-rex* looks at us with a small beady eye, but it is its open mouth and teeth more than its eyes that make a demand on us, menace us and perhaps instil fear.

The perspective of the picture is strange with the head shown much bigger than the rest of the body, making the animal loom out of the page at us, appearing almost three-dimensional, and making the animal's demand on us more urgent. This perspective gives the impression that the *T-rex* is close to us: too close for comfort (or as the caption of the *Liopleurodon* photograph says 'upclose and personal'). This photograph indicates that the article contains more than information; it engages our attention and is thus attractive to the reader. Is this engaging quality to invite the reader to read the article, to draw the reader in? Or is it, in line with the cynical tone of the writing in the article, inviting us to be cynical about this exaggerated dinosaur with the enormous mouth and ferocious teeth which, as the headline says 'won't go away'?

The image of the *T-rex* is less realistically presented than that of the *Liopleurodon*. Firstly, there is no background - the newsprint is the background. As discussed above, perspective is exaggerated; the head is exaggeratedly large compared to the body, giving a cartoon-like impression. The representation is highly detailed; we see the texture of the skin and of the teeth in a way that is perhaps overly realistic. By contrast, the tongue looks slightly artificial, and may be computer generated. Overall this image is a far better illustration than the *Liopleurodon* of the written text's contention that dinosaurs, "loud gormless and likely to bite your head off, ... were just made for a successful light entertainment show" (Matthews 1999:23, see appendix page 35).

In summary, the photographs attract our interest and are primary in this text. The first is from a current TV documentary, the other is the classical image of dinosaurs, the T-rex. Both give an impression of menace, with us the reader as the goal of the menace. The T-rex in particular has escaped from its frame and is eating the words of the article. It emphasises the title of the article, that dinosaurs 'won't go away'. The T-rex is also exaggerated in size and thus contributes to the humorous intent of the article. Both appear to be real photographs of real living animals, and so have high truth-value.

4.4.3.2 Contact, affect and status in the Mail and Guardian article

Contact refers to the writer's solidarity with readers, affect to 'positive or negative attitude of the writers to the readers and what they are talking about' and status to how the writer includes the reader (Gerot 1995:104). These concepts are prominent in the account that follows.

Contact in the Mail and Guardian extract

There is a fair amount of clausal ellipsis which gives the extract a cryptic/conversational feel and contributes to its informality (see 4.4.2.5 above). This informality indicates equality between the writer and reader. Another point of contact between writer and reader is the humorous tone of the article expressed lexically (sure-fire, get rid of, zapping, trashing, sorted the big oafs out, etc). The writer also expresses solidarity with the reader by including the reader and writer together in a group of sensible commonsense people and scientists as a group with far-fetched ideas, whose theories can be reasonably easily seen through and dismissed. The text has many reliability hedges (see 4.4.3.3 below) indicating the degree of skepticism of the writer. The writer is popularising science for a readership who are expected to be critical of science and expected to view scientists as a group likely to be motivated by qualities other than objectivity.

Sympathy in this article is with the non-specialist reader who is twice included in the text: [6]*since then **we have had** death by genetic changes*... and [8b]*That ought to have sorted the big oafs out, **you would think.*** This inclusion is done very casually, serving the jocular/humorous intention of the text, but implying, firstly, that the readers have long been aware of the series of new theories for dinosaur extinction, and, secondly, that the readers are the ones doing the thinking about dinosaur extinction.

Affect in the Mail and Guardian extract

Academics and palaeontologists are treated flippantly and without the respect they are afforded in the other texts in my data: from the research articles to the Time and Scientific American articles, the texts for children and the textbooks. Academics in this extract would [12]*naturally prefer* a simple explanation; in fact some of them [13]*insist there is only one explanation (namely their own)*. Some palaeontologists suspect that speculation on the fate of the dinosaurs is [1b]*another source of trivialisation of their subject* – as if there are many sources of trivialisation of palaeontology; we are told what [10a]*most right-thinking palaeontologists* think – with the implication that a number of palaeontologists can be dismissed as wrong-thinking. The theories of these palaeontologists are recounted in humorous terms; [3]*hardly a week goes by* without their come up with new theories for [3]*zapping the dinosaurs*. Their theories are recounted in terms reminiscent of a murder mystery: [6]death by volcanic eruption, [6]*death by genetic changes*, [6]*death by continental breakup*, [6]*death by meteor impact* and [11]*death by all of the above*. This "what will they come up with next?" tone indicates that academics and palaeontologists are certainly not the intended readers of the article.

The article is humorous in intention, and the humour is more important than an appearance of objectivity. However the writer achieves a certain appearance of objectivity by claiming that the views expressed are those that would be shared by any reasonable person:
[10a]*Most* ***right-thinking*** *palaeontologists today do not believe*; [8a]*That ought to have sorted the big oafs out*, [8b]***you*** *would think*. [**you** is the reader, the ordinary reasonable person]

Scientists are viewed as a petulant group who have foisted a series of implausible theories on the public ([6]*we*, [8b]*you*); they are not objective but apparently motivated by a liking for their own ideas ([13]*their own explanation*). A group treated even more flippantly and unsympathetically than palaeontologists and academics is the dinosaurs themselves who are characterised as [8a]*big oafs*. On the whole, dinosaurs as a phenomenon or topic of discussion are seen as tedious and over-publicised: the article's title is *Why dinosaurs won't go away*. The author speaks of [2]*the fact that no way has been found to get rid of dinosaurs*, humorously conflating the extinction of the dinosaurs with removing them as a topic. Their extinction is variously referred to in terms of [3]*zapping the dinosaurs*, [8a]*sort* (them) *out*, [19]*do* (them) *in*, and [10c]*knock T-rex off his perch*. What killed them is [11]*a multiple-whammy of volcanic eruptions genetic and geological changes – with a meteor impact chaser*.

This is in contrast with both the children's literature on the topic (cf. section 4.5), where dinosaurs are also the central topic but are treated seriously, and the Scientific American article (cf. 4.3) where dinosaurs are peripheral, but treated as a serious topic of interest. On the other hand the tone of the Mail and Guardian article has most similarity with the Scientific American article which also makes a judgement on one of the theories under discussion and treats it ironically. Presumably this has once again to do with the intended readership of the different publications: children who like dinosaurs (Children's books); scientists and those interested in science who are largely not Palaeontologists or Geologists and thus are looking for some summary of research in the field and some judgement of the worth of the research (Scientific American); and adults who do not trust scientists (Mail and Guardian).

Status in the Mail and Guardian extract

As explained above, the writer includes the reader by characterising scientists as the Other. This implies that scientists are not the intended readers of the article. They, their ideas, their discipline and their approach to knowledge are treated flippantly and with little respect. The non-specialist reader and the writer, on the other hand, are characterised as ordinary sensible people: we ([6]*since then we **have had** death by genetic changes*...) and you ([8b]*That ought to have sorted the big oafs out, **you would think***). We ordinary people are in the unfortunate position of having our commonsense ideas contradicted in the article.

4.4.3.3 Hedging in the Mail and Guardian extract

The analysis in Table 4.4.8 indicates that unlike the other two popular articles there are few writer-oriented hedges and most hedges are reliability hedges. Reflecting a projected readership of non-scientists, the writer wants to indicate his assessment of the reliability of propositions rather than shield himself from reader objections to what he says.

Most hedges are reliability hedges (six), with one attribute hedge, one writer-oriented and one reader-oriented hedge. This is similar to the children's texts where reliability hedges are prominent and unlike the Scientific American article, where writer-oriented hedges are prominent. This reflects the different readership of the Scientific American and Mail and Guardian. In the former, the participants in the text are likely to read the article, and other readers besides the participants are likely to have a good knowledge of the field. Thus the writer has to shield him/herself from challenges to what is said by indicating what the source of the information is – i.e. by citations. In the Mail and Guardian by contrast, there is far less likelihood of those with a good knowledge of the field reading the article. The projected readers are not scientists. The writer therefore feels less necessity to cite sources or limit his commitment. Furthermore, it is plain that the writer is exaggerating for humorous effect, and is thus unlikely to be challenged.

Table 4.4.8 Hedging in the Mail and Guardian extract following Hyland 1996

	Hedges	Reason for the hedge
1b	**At least** it is among those who …	Reliability hedge: writer has less than full warrant for categorical assertion (Hyland 1996c: 440)
2	… that no… way has been found … is **perhaps** the most telling tribute …	Attribute hedge: "downtoners that weaken the force of an attribute" Hyland (1996c: 441)
3	**Hardly** a week goes by without some new theory …	Writer-oriented hedge. It appears at first to be an attribute hedge where writer uses a downtoner to weaken the force of an attribute. But actually the writer is exaggerating, so I view this as a writer-oriented hedge where the writer wishes to exaggerate but does not want to be accused of it so introduces an element of vagueness to shield the writer from opposition
5a	These **could have blotted out** …	Reliability: assessment of reliability of propositional validity.
7	… at something like 96 000kph	Attribute hedge – specify precisely
8a	That **ought to have** sorted the big oafs out…	Reliability hedge – the writer is using this hedge to indicate that the proposition that 'that sorted them out' is not reliable.
8b	…**you would think**	Reader-oriented: draws reader into the article/argument.
12	Academics **would** naturally **prefer** that the explanation … were simple	Reliability – because it implies 'but actually its not simple'.
13	… those who **insist** there is only one explanation **(namely their own)**	Reliability – because both 'insist' and '(namely their own)' imply that the idea of one explanation is untrue.
	Only … several catastrophes striking all at the same time **could** finally …	Reliability – this is not a hard and fast established fact – the writer is reporting an argument to this effect.

4.4.3.4 Evaluation in the Mail and Guardian extract

Evaluation is a category that includes all meaning that functions to express the writer's opinion and value system, and construct and maintain relations between writer and reader (Thompson and Hunston, 2000:6). I begin, in Table 4.4.9, by considering evaluation in each clause as suggested by Hunston (1993, 1994).

It is difficult in this text to decide who the source is for a lot of what is said. For example, is the source of information in clause 10 paleontologists or the author? In clause 13 is the source the writer or academics? The writer claims that [12]*academics would naturally* *prefer*... and that [10a]*most right-thinking paleontologists today do not believe*..., but we are not told which academics and paleontologists. We have only the writer's word for it.

The analysis in Table 4.4.9 shows that two main hypotheses are put forward: the single cause and the multiple cause hypotheses. In terms of Certainty, although a single cause is rated as 'possible' in clauses 4-7, in clauses 8-11 and clauses 12-14 is rated unlikely and untrue. So a number of single cause hypotheses are 'set up' in clause 4-7 to be knocked down in clause 8-11. Instead the multiple cause hypothesis is rated as probable (clause 11 and clause 19).

Table 4.4 9 Evaluation in the Mail and Guardian extract

Status					Value
Clause	Activity	Source	Modification	Certainty	value
1a	assess	writer		certain	+ current
1b	state fact	writer	at least	certain	- importance
2	State fact	writer	perhaps	possible	
3	State fact	writer	Hardly	certain	+ current
4	hypothesis	Headlines/news		possible	**Hypotheses – single cause**
5a	hypothesis	News	could have blotted out	possible	
5b	hypothesis	News		Possible	
5c	hypothesis	News		possible	
6	hypothesis	news		possible	+ famous
7	hypothesis	News or unspecified RA	something like	possible	+ spectacular
8a	hypothesis	writer	ought to have, you would think	unlikely	
8b	project				
9	assess	writer		untrue	
10a	project				
10b	hypothesis	Paleontolgists/ writer	do not believe	unlikely	-reasonable
11	hypothesis	Paleontolgists/ writer	subscribe	probable	**Hypothesis – Multiple cause**
12	hypothesis	Academics/ writer	prefer	unlikely	**Hypothesis – single cause**
13	State fact	Academics/ writer	insist	unlikely	
14	Fact/assess	writer		unlikely	- reasonable
15	State fact	Accepted knowledge		known	
16	State fact	writer		known	
17	question	writer			
18	Fact/assess	writer		certain	
19	assess	writer	could do in	probable	+ reasonable

In terms of Value, the author is ambivalent about the topic as a whole. Although dinosaurs as a topic are very current and popular, as discussed above, the author views the topic as over-rated and boring. As Table 4.4.9 shows, he rates them as unimportant (trivialising of paleontology). Comparing the single and multiple cause hypotheses, the single cause idea is rated unreasonable (poor fit to expectation and other knowledge) while the multiple cause hypothesis is rated as reasonable.

Overall, if we compare this text to, for example, the Scientific American article, the Mail and Guardian writer

- Is freer with overt negative judgements (big oafs, right-thinking paleontologists)
- Does not provide the source of information but peoples the text with a generic group of academics and paleontologists
- Spends much of the extract knocking down the single cause hypothesis and much less of it in elaborating the hypothesis claimed by the article to be current and reasonable (the multiple cause hypothesis). So focus is on the fact of the debate as much as on the results of the debate and the ideas it advances. It assumes that readers are as much interested in the gossip about the topic as in the ideas generated by it.
- Aims to be humorous and uses deliberately informal lexis (*sure-fire, get rid of, zapping, trashing, sorted the big oafs out*, etc) to achieve this.

This reflects a readership that takes the general topic (dinosaurs, paleontology and, more broadly, science) less seriously than do the readers of the Scientific American article. This is not to say that the Mail and Guardian readers necessarily rate science as unimportant, but merely that it is less central for them than for the Scientific American readers. The witty/humorous tone is consistent with other articles in the Mail and Guardian particularly articles not dealing with current news. This is true of many newspapers.

Table 4 4.10 Alternate negative and positive evaluation in the Mail and Guardian

Clause complex	**status**	**value**
1-3	Fact, writer, certain	+ current
4-7	Hypotheses, news, possible	**Hypothesis: single cause** + famous, spectacular
8		
9		
10	Hypothesis, palaeontologists, unlikely	- reasonable
11	Hypothesis, palaeontologists, probable	**Hypothesis: multiple cause**
12 - 14	Hypothesis, palaeontologists, unlikely	**Hypothesis: single cause** - reasonable
15 - 19	Fact/assess, writer, known/probable	+ reasonable

Like the Scientific American article, the Mail and Guardian article sets up an opposition between two hypotheses: the single-cause and multiple-cause hypotheses. Table 4.4.10

shows that the text sets up a series of single cause hypotheses but then knocks them down with the multiple- cause hypothesis. The topic as a whole is assessed positively as current ([1a]*hot topic*). A series of single cause hypotheses are proposed, each undercut firstly by trivialising echoes from murder mysteries ([6]*death by genetic changes*) and then by an assessment of a single cause by [10a]*right-thinking palaeontologists* as unlikely (status) and unreasonable (value). A multiple cause is then assessed as reasonable and a single cause once again as unreasonable.

Interestingly, a strong value in both the Mail and Guardian article and the Time article (see clause 1, 2a, 3b) is that of being current/famous/spectacular. This is a value not cited at all by Hunston (1993), and is apparently not present as a value in research articles.

Compared to the Scientific American article there is less engagement with ideas in the Mail and Guardian article because no real evidence or research findings are presented in support of one or other hypothesis. This perhaps reflects the depth of interest in the topic of the readers, and the extent to which they can be presumed to have followed the story. Readers of Scientific American have been exposed to previous articles on the topic of what caused the extinction of the dinosaurs, while the same is less likely to be true of readers of the *Mail and Guardian*.

In summary, as in the Time and Scientific American articles, there is sequential, positive and negative evaluation of hypotheses – in this case a single cause and a multiple cause hypothesis. Compared to the other popular articles, this article makes more overt negative judgements, is humorous in tone and sets up hypotheses for the purpose of undercutting them and proving them wrong.

4.4.3.5 Summary and overview of Tenor in the Mail and Guardian article

The reader and writer of the Mail and Guardian article are regarded as reasonable people and as equals. Scientists, by contrast, are regarded as not objective and ready to foist far-fetched theories on the long-suffering reader and writer. The readers are not expected to be scientists as reflected in the lack of writer oriented hedges/lack of indication of the source of information. As in the Time article, scientists are 'other', but unlike in the Time article they are viewed negatively. This reflects the expected readers of the article as non-scientists (as in Time) but non-scientists who are suspicious of the findings and intentions of science and do not, like the readers of Time, view science as synonymous with progress The subject of palaeontology is viewed as trivial and dinosaurs as boring and over-worked. The photographs depict dinosaurs as menacing but also as exaggerated and humorous. Unlike all other texts in this study the writer is more concerned to amuse than to inform the reader. This is reflected in humorous attitudinal lexis, and clausal ellipsis.

4.4.4 Summary and overview of Register in the Mail and Guardian article

My analysis of this article indicates that it is different from all the other texts in the study in a number of ways: firstly, it does not seek primarily to inform but rather to amuse the reader, and, secondly, there is overt negative evaluation of scientists and dinosaurs. The text is far less impersonal than the other texts in the study and the writer clearly identifies the reader and writer as being in one group. The text is about how an unsympathetic and subjective group of generic scientists have foisted a series of far-fetched theories about dinosaur extinction (a boring and over-worked topic) on the reasonable public including the reader and writer. In terms of field (but not tenor) the text is similar to the other texts for non-scientists (Trefil and Hazen and the books for children) in that dinosaurs are fairly central, and the text is not abstract. Organisation of the text (using theme, conjunctive relations ellipsis and nominalisation) serves the text's humorous intention by setting up various theories and then indicating that they are wrong.

4.4.5 Genre in the Mail and Guardian article

As discussed in section 2.5, White (1997) identifies two genres within the media: hard news reporting, and commentary or opinion. By contrast with hard news, in commentary or opinion the role of the author is to offer subjective interpretations with explicit value judgements. The Mail and Guardian article is an opinion piece with frequent interpersonal value judgements about the competence and motivations of scientists. This is distinguished from The Scientific American and Time texts, which fall into one of the sub-genres of hard news reporting, the issues report.

As an example of an opinion piece, this article is the only text in the study that makes little attempt to appear objective. Amusing the reader is more important than objective information (although the article aims to be informative as well as amusing). By contrast the Time article, and in particular the Scientific American article, emphasise information above amusement.

Like other popular sources in this study such as Time and Scientific American, the readers of the Mail and Guardian are an educated group. Like the readership of Time the readership of the Mail and Guardian is broader than the readership of Scientific American in not being limited to people with a specific interest in science. The Mail and Guardian is fairly left-wing in outlook and prides itself on being critical of powerful institutions such as government and big business. This is also reflected in this article in the cynical tone it takes to the institutions of academia and science in general.

4.4.6 Ideology in the Mail and Guardian article

This text is the single example in this study of a text participating in the ideologies of science as boring on the one hand, and of scientists as a subjective, unreliable, cynical group motivated by the desire to advance their own theories, not by a wish to find out the truth/facts on the other. The first of these, science as boring, is very widespread in popular culture. It is, I believe, like the ideologies of science as difficult, and science as authoritative, likely to make science more difficult to learn. It is related to the image of the scientist as 'geek' or 'nerd', the highly intelligent but socially inept individual. As discussed in chapter 4.3, there is some evidence of this image of the scientist in the Time article.

The second of these ideologies, scientists as a rather sinister and self-serving group, indicates an ideological strategy indicated by Eagleton (1991): that of mystification. Academics and palaeontologists are viewed cynically and with mistrust. They are a group apart and different from the readers: they are Other. In the Time article, although treated as Other, scientists are on the whole positively presented (as having religious authority and as being highly intelligent) In the Mail and Guardian extract, on the other hand, scientists and their motives are less to be trusted. This reflects a sceptical and 'investigative' trend and in the journalism on which the Mail and Guardian prides itself, particularly towards groups perceived to be powerful such as politicians, and big business Scientists appear to be included in this scepticism as one of these powerful groups. It is also true that Science has always been treated cynically by those on the political left in South Africa, and the Mail and Guardian can be regarded as the most left wing of mainstream South African newspapers. Reflecting this, in the Time article, scientists are real, named individuals, while in the Mail and Guardian article they are a generic group of 'academics' and 'palaeotologists'.

It is not that the text has a different idea of facts from the other texts. It is still clear that within the value-system of the article there is such a thing as objective facts. The word 'fact' is mentioned twice:

[2]*The fact that no single, sure-fire way has been found to get rid of dinosaurs is perhaps the most telling tribute science has yet paid them.*
[14]*But there is one last, humungous fact standing in the way of all one shot kills all theories.*

The reference to 'fact' in clause 2 is for the purpose of constructing a fact clause – i.e assigning as factual status to [2]*no single, sure-fire way has been found to get rid of dinosaurs*. This makes this statement into an embedded clause making it less likely that the reader will ask 'found by who?' or 'why would anyone want to?'

The reference to 'fact' in clause 14 however has the implication of 'scientific fact' or 'accepted by science'. The 'fact' referred to is that [15]*Dinosaurs were the dominant life form on this planet for 160-million years*. Thus, in spite of mistrusting science and scientists, the writer subscribes to the idea of objective scientific facts outside of time and place and independent of people. Ironically, it is the 'wrong-thinking palaeontologists' and academics that overlook and ignore the [14]*humungous facts*, and the author that has to reassert them.

4.4.7 Summary

In summary, the main purpose of this text is to entertain the reader. Writing an opinion piece, the writer does not attempt to be objective but uses a lot of attitudinal lexis and subjective language in giving his own opinion. Information is secondary to humour in the article. The persona projected by the writer is of a non-scientist who views the readers as non-scientists too. As in the other popular texts a relationship of equality is projected between reader and writer. By contrast with the other two popular articles in this study, this article is not sympathetic to science or scientists. Scientists are viewed as unreliable, subjective and self-serving. They are present in the article only as a generic group and although they have thoughts attributed to them, they do not collocate with verbal processes and have no words attributed to them. Science, in the topic of dinosaurs at least, is viewed as boring. The article thus subscribes to two negative ideologies about science: science as boring and science as sinister.

The writer uses informal lexis (like [8a]*big oafs*) and clausal ellipsis to give the extract a conversational feeling and to add to the humour of the article. One of the two photographs is humorously exaggerated, supporting the contention of the article title that dinosaurs *won't go away*. Thematic development and conjunction function repeatedly in the setting up of false expectations which the writer then humorously disappoints.

Overall, lexis and clausal ellipsis contribute to the humour of the article. Generic scientists who never speak for themselves and are viewed with cynicism contribute to a negative impression of science and scientists. Thematic development, conjunction and nominalisation allow the writer to set up theories of dinosaur extinction and then humorously knock them down in the next clause.

4.5 Science books for children

4.5.0 Introduction

I began my examination of science books for children as a genre, by analysing extracts from four texts in detail. I found that three of these four books were very similar. The fourth was unusual for the genre, in my experience, in that it contained a narrative as well as a factual section. I have selected one of the four texts as exemplary of the genre. A full analysis of this text is provided in this chapter, but I make frequent reference and comparison to the other three texts, as I have done in the case of textbooks and popular journal articles.

I have selected a 480-word text called Prehistoric Life (see foldout in appendix page 46) as my exemplary text. The two texts that are very similar to Prehistoric Life are All about Dinosaurs (appendix page 37), and DK Picturepedia (appendix page 40). The more unusual text is Tyrannosauraus rex (appendix page 49). As with my analysis of the other texts in this section I consider the context of situation, or register, of Prehistoric Life by analysing the text in terms of Field (in 4.5.1), Mode (in 4.5.2) and Tenor (in 4.5.3). I then go on in section 4.5.5 to consider the context of culture, or genre, of the text, before moving on to a consideration of ideology in 4.5.6. My analysis below reveals that science books for children show similarities with textbooks in the human participants who are included, in the kind of hedging that predominates and in the attitude to science that is prevalent in the texts.

4.5.1 Field in the books for children

This section, as is the general pattern for chapter 4, examines human participants, processes and other participants and circumstances.

4.5.1.1 Human participants

Table 4.5.1 lists all human participants in Prehistoric Life, and the other three books for children and indicates whether they appear in the major position in the clause and whether they are specific people or merely generic representatives of a group.

Table 4.5.1: Human participants in the books for children

	All about Dinosaurs	major/minor: generic/specific
3	We are not sure (*attributive*)	major; generic?
4a	Scientists thought (*mental*)	major; generic
10a	Some scientists think (*mental*)	major; generic
14a	No one knows (*mental*)	major; generic
	DK Picturepedia	
2a	We can tell (*mental*)	major: generic
3a	we know (*mental*)	major: generic
4a	We can guess (*mental*)	major: generic
12a	Some scientists believe (*mental*)	major; generic
17a	Scientists think (*mental*)	major; generic
	Prehistoric Life	
5b	no one knows (*mental*)	major; generic
6a	Some scientists think (*mental*)	major; generic
7a	They believe (*mental*)	major; generic
19a	Scientists call (*verbal*)	minor; generic
21b	both groups of scientists are right (*attributive*)	minor; generic
	Tyrannosaurus Rex	
	no human participants	

As can be seen, the human participants in three of the texts All about Dinosaurs, DK Picturepedia and Prehistoric Life were identical: *scientists* and *no one*. All about Dinosaurs, and DK Picturepedia also refer to '*we*' in '*We can guess*' and '*We are not sure*'. This identifies the child reader with the writer and with scientists in that 'we' are the ones involved in thinking about and working out what happened. The fourth children's book has no human participants. In all three texts *we know/don't know* things; *scientists think believe call* and *are right*; *no one knows*. These three texts are also similar to each other in what these participants do: largely mental processes. Human participants in the books for children are generic, indicating that humans/scientists are not the focus of the accounts. In this the texts have similarities with textbooks (cf. 4.2) in that the facts of what happened to the dinosaurs are important, not the people who discover these facts.

4.5.1.2 Processes, participants and circumstances

In what follows I consider the participants and processes in Prehistoric Life, making comparisons with the other three texts for children. Table 4.5.2 summarises the kinds of process in the other three books, thus indicating the extent to which Prehistoric Life is similar to them.

Table 4.5.2 Proportions of different process type in four books for children

	material	mental	identifying	attributive	existential	total
All about Dinosaurs	11 (58%)	3	1	4		19
DK Picturepedia	23 (52%)	8	5	7	1	44
Prehistoric Life	14 (41%)	3	5	11 (32%)	1	34
Tyrannosauraus rex	32 (68%)		3	5	7	47
	80 (56%)	14 (10%)	14 (10%)	27 (19%)	9	144

Table 4.5.3 lists the processes in all clauses in Prehistoric Life. Plants and animals other than dinosaurs ([2b]*a number of other groups, such as...*, [4]*fish crocodiles turtles ...*, [3]*all living things*, [17]*Many of the plants both on land and in the sea*, [25]*other reptiles such as ...*[26]*many other groups including...*, [24]*a squidlike creature called an ammonite*, [6b]*other groups that became extinct*) are mentioned more frequently than dinosaurs (which are mentioned four times).

In terms of ideas, Prehistoric Life is very well informed about and summarises the recent research. For example it mentions the two opposing explanations for the mass extinction at the end of the Cretaceous: gradualism and meteorite impact and tries to reconcile them: [23]*It is possible that both groups of scientists are right.*

As with the other three texts for children, material processes make up about half of the processes in the text. Thus the texts are grounded in the physical world rather than the world of consciousness or abstract relations. There are no verbal processes in Prehistoric Life or in any of the other texts. This is because the writers of all three texts do not cite specific sources as is the way in the popular articles and research article. Attributive processes are fairly common serving to paint a vivid picture by saying things are [21b]*hotter,* [7b]*cooler,* [4]*unchanged,* [2a,6b]*extinct* etc.

Table 4.5.3: Processes and participants: Prehistoric Life

	Actor	**Material**	**Goal**	**Circumstance**
3	all living things	were not affected		
5a	these extinctions	happened		65 million years ago,
7c	the seas	were draining back		from the continents
7d	the many volcanic eruptions at the time	were throwing up	great quantities of dust	into the atmosphere.
11	The Cretaceous meteorite	could have made	a crater 159 times this size	
14		has been found	A huge crater that could have …	near the north coast of Mexico.
16a	This debris	could have darkened	the skies	for many years
17	Many of the plants, both on …	would have died		from lack of light.
18a	the plant-eating dinosaurs …	died		in their turn.
20a	the thick dust	had settled		
20b	the long winter	ended		
21b		making	the climate much hotter,	
25	Other reptiles such as…	survived	the extinction,	
26	Many other groups … including …	disappeared		as well as dinosaurs,
		Existential	**Existent**	
13	there	is	evidence that … FACT	
	Senser	**Mental**	**Phenomenon**	
5b	no one	knows	FACT	
6a	Some scientists	think	FACT	
7a	They	believe	FACT	
	Token	**Ident: intens**	**Value**	
9	The Yucatán area of Mexico	may have been	the site of the meteorite impact.	
	Token	**Ident: circum**	**Value**	
8	The huge impact of a large meteorite	would have caused	earthquakes and tidal waves …	
16b		causing	a long, cold winter.	
21a	These	would have caused	what scientists call …	
22	These two … changes	would have caused	very rapid extinctions, …	
	Carrier	**Attributive**	**Attribute**	
1	what	went	wrong?	
2a	dinosaurs	became	extinct	at the end of the Cretaceous period…
2b	a number of other groups, such as …	did		
4	Fish, crocodiles, turtles, birds, …	managed to survive	unchanged	
6b	dinosaurs, and other groups that …	were becoming	less numerous and varied	for several million years before…

7b	the climate	may have become	cooler	
10	This meteorite crater	is	1.2 kilometres wide	
15	Rocks all over the world ...	contain	unusual minerals which ...	
20c	the atmosphere	would have contained	a lot of finer dust	from the rocks thrown up by ...
23	It FACT (that both groups ...are right...)	is	possible	
24	This fossilised shell	belonged to	a squid-like creature called an ammonite.	

Prehistoric Life contains a single intensive and three circumstantial identifying processes, all three of which are causal. In Prehistoric Life, as in one other book for children, DK Picturepedia, causal relations are realised as identifying processes as well as congruently through conjunctions. Table 4.5.2 indicates that on the whole identifying processes are not common in the books for children. Halliday (1994:126) characterises identifying processes as dominating "certain highly valued registers (such as scientific ...discourse) where the meanings that are being construed are inherently symbolic ones". This confirms the books for children as rather concrete, and grounded in the physical rather than symbolic world.

Tyrannosauraus rex is unusual in that the first part (clause 2-9) is written as a narrative account of something that actually happened. The only hint that this may not be a factual account is the question in the title '*The end of the dinosaurs?*' The language in this section is fanciful:

[2a]*an asteroid streaked out of space;* [3a]*The earth shuddered;* [4a]*The sun danced in the sky;* [9a]*Little scuttling mammals rooted for food in the wasteland;* There was: [5b]*the darkness of early night;* [5c]*no moon or stars, just the glow of volcanoes;* [6]*the smell of hot dust and burning.*

On the whole, it appears that writers of children's science employ a variety of techniques to make the writing more accessible. One of these techniques (not commonly used in this selection) is fiction/fantasy/narrative. There is greater use of material processes, invariably grounded in real world happenings, than of identifying processes. The relational processes are more commonly attributive, contributing to the vividness of the description. Other techniques used to make the writing more accessible are short nominal groups, and few words per clause.

Circumstances in the books for children

Circumstances of place and time are particularly important in the texts for children. This is similar to the other genres in the study. Table 4.5.4 shows the kinds of circumstances in the four texts. The circumstances of place in the books for children largely concern where on the Earth ([14]*near the north coast of Mexico*;), and in space (Tyrannosauraus rex: [2a]*out of space*; All about Dinosaurs: [11a]*around the Earth*). Circumstances of time largely concern the time of the dinosaurs ([2a]*at the end of the Cretaceous period*).

Table 4.5.4 Circumstances in the books for children

	All about Dinosaurs	DK Picturepedia	Prehistoric Life	Tyrannosaurus Rex
Extent: temporal		2	1	2 (10%)
Location: place	1	**9 (36%)**	**3 (27%)**	**11 (52%)**
Location: time	**3 (50%)**	**7 (28%)**	**4 (36%)**	1
Manner	1	**5 (20%)**	1	**5 (24%)**
Cause	1	1	**2 (18%)**	2 (10%)
Accompaniment		1		
	6	25	11	21

Lexis in the texts for children

All four texts are in agreement on the lexis used in connection with dinosaurs. In all four texts death and destruction are almost the only things associated with dinosaurs. We are told that dinosaurs [2a,6b]*became extinct*, [26]*disappeared*, [6b]*became less numerous and less successful*. They are speculated to have died of a wide range of things: [8]*a meteorite*, [7d]*volcanic eruptions* [16a]*the cold*. All four texts offer possibilities for the reason for the mass extinction. As with the lexis associated with dinosaurs, the lexis associated with mammals and other creatures is similar in the four texts: mammals and other forms survived, and may in fact have hastened the end of the dinosaurs. Thus mammals and other extant organisms are set in strong contrast to the dinosaurs They [2]*managed to survive*, [25]*survived*.

As with dinosaurs and mammals, the lexis associated with weather and climate in the four texts is similar. All four texts speak of the earth becoming colder or warmer or both in succession. The weather [7b]*may have become cooler*. We are told of *icy winters*, [16b]*a long cold winter*. On the other hand there is a [21a]*greenhouse effect, making the climate much hotter*, and *the gradual warming of the Earth*.

Meteorites are advanced by all four texts as a possible cause of the dinosaur extinction. The meteorite/asteroid is a violent body with disastrous consequences: it [13]*struck*, resulting in [14]*a crater*. Two of the texts suggest evidence for this extraterrestrial body in the form of unusual minerals from the material of the meteorite (Prehistoric Life and DK Picturepedia).

The texts for children are engaging in terms of asking questions (All about Dinosaurs), using personal language, using narrative in the case of Tyrannosauraus rex, and using exaggerated expressions like 'blown to smithereens' (Tyrannosauraus rex). Nevertheless I regard the offering of evidence as well as the offering of alternative theories in all four texts as indicators of the fact that although for children, and thus different in a number of ways, these texts are nevertheless factual scientific texts with much in common with other genres of scientific writing. I therefore speculate that texts such as these are a step on the path to more adult forms of scientific writing - ultimately a step on the path to the research article genre. This idea I develop further in section 5.5.1.

4.5.1.3 Summary and overview of Field in the books for children

As in textbooks, human participants in the books for children are generic, indicating that the facts are more important than who first suggested the facts. In all four texts material processes are the most common type of process. These invariably realise real world meanings, and the focus of the texts is the dinosaurs and what happened to them in the Cretaceous period. These happenings are not used to make a point about the nature of evolution as they are in the three textbooks examined. As a result, the texts are literal rather than abstract. As indicated above '*scientists*' and '*we*' are the agents of the mental processes, and this, I argue below, identifies the child reader with scientists. Mental processes also realise causal relations. The identifying processes are causal in Prehistoric Life and in one other text. In addition, the books for children are alone in this study in realising cause partly through conjunctive relations rather than identifying processes.

4.5.2 Mode in the books for children

The analysis below considers thematic structure, embedded clauses, nominalisation, passivisation and conjunctive relations.

4.5.2.1 Theme in the books for children

The books for children all employ hyperthemes in the form of headings and subheadings. The thematic development of Prehistoric Life is more sophisticated than that of the other three children's books. I therefore include for comparison a full analysis of theme of one of the other books for children, All about Dinosaurs, which in this feature is more similar to the other two texts. In brief, the thematic development of the four texts is as follows:

- Prehistoric Life combines the use of subheadings (hypertheme), β clause as theme at the beginning of new paragraphs/stages in the argument, and 'heavy' themes, that make thematic extra information about the theory of extinction favoured by the author.
- In All about Dinosaurs the main heading is a hypertheme from which hangs a series of little paragraphs each of which combines adjuncts as marked theme, adversative conjunctions and interpersonal themes (questions).
- DK Picturepedia employs hyperthemes found in the first (summary) paragraph and expanded on later in different sections of the text. This is combined with subheadings. There is also a good deal of theme maintenance and some progression of theme.
- Tyrannosauraus rex employs subheadings (as hyperthemes) and in the factual sections there is maintenance of theme and some numbering to organise the text.

Theme in All about Dinosaurs

Table 4.5.5 contains a clause by clause analysis of theme in All about Dinosaurs. The title of this text, '*What happened?*', is a hypertheme for the whole text. From this hypertheme hang a series of little paragraphs, each of which combines two or three of the following themes: adjuncts as marked theme, adversative conjunction as textual theme, and interpersonal themes/questions.

Remarkable about thematic choice in All about Dinosaurs are the high number of wh-adjuncts: what, why, how, why and which. These make the text into a series of questions the answers to which are ultimately unknown as the text makes clear in the final clause ([14]*No one knows which is the right answer*).

Many of the themes signal progression of what the text is about (selecting a constituent from the preceding rheme). The two marked themes are both circumstantial adjuncts of location in time. The first of these, [2]*Sixty-six million years ago*, places the mass extinction in time, while the second, [4a]*At one time*, places scientific interest in the mass extinction in time.

Table 4.5.5 Theme in All about Dinosaurs

	Textual	**Interpersonal**	**Topical**	**Rheme/ markedness**
1		Wh...	...at	Interpersonal
2			Sixty-six million years ago,	Location: time
3			We	
4a			At one time,	Location: time
4b	that		the early mammals	
5a	But		dinosaurs	Adversative
5b	and		their eggs	
6	So	h...	...ow	Interpersonal causal
7			Another idea	
8	But		this *change* of climate	adversative
9	So	wh...	...y	Interpersonal causal
10a			Some scientists	
10b	that		a giant meteorite ten kilometres wide	
10c	and		*	
11a			The great *explosion*	
11b	and		many animals	
12	But		crocodiles, frogs, birds and mammals	Adversative
13			These animals	
14			No one	

Arrows indicate maintenance of theme Arrows indicate progression of theme
Clause as theme: bold; marked theme: underlined; *nominalisations: italicised*
* means the theme is carried over from the previous clause

Martin (1993:247) shows that method of development of a text is often predicted by a clause (or series of clauses), which function as 'hypertheme' to the text following it. As he puts it, hypertheme is to paragraph what theme is to clause. This is certainly the case for All about Dinosaurs. The entire text hangs from the question posed by clause 1: *What happened*? An answer is offered in clause 2, and then each little paragraph offers a possible explanation for why this happened. These little paragraphs start in some cases with adjuncts as marked themes (clauses 2 and 4a), are followed in some cases (5a, 8 and 12) by adversative conjunctions indicating objections to the solution offered in the paragraph. In some cases the final clause in the paragraph has an interpersonal theme, a question (clause 6 and 9). Martin (1993:246) characterises this interaction between Hypertheme and method of development as characteristic of the Report genre.

Theme in Prehistoric Life

Table 4.5.6 Theme in Prehistoric Life

	Textual	Interpersonal	Topical	Rheme/ markedness
1		Wh...	...at	interpersonal
2a			**When dinosaurs became extinct at the end of the Cretaceous period 65 million years ago**	Clause as theme
3	But		not all living things	adversative
4			Fish, crocodiles, turtles, birds, mammals and most flowering plants	'heavy' theme
5a			**Because these *extinctions* happened 65 million years ago**	Clause as theme
6a			Some scientists	
6b			dinosaurs and other groups that became extinct	'heavy' theme
7a			They	
7b			the climate	
7c	because	perhaps	the seas	cause impersonal
7d	and because		the many volcanic eruptions at the time	cause
8			The huge impact of a large meteorite	
9			The Yucatán area of Mexico	
10			This meteorite crater	
11			The Cretaceous meteorite	
12			Meteorite Impact	
13	But		there	adversative
14			A huge crater [[that could have been caused by such an impact]]	'heavy' theme
15			Rocks [[all over the world laid down at that time]]	'heavy' theme
16a			This debris	
16b			*	
17			Many of the plants, [both on land and in the sea,]	'heavy' theme
18	Then		the *plant-eating* dinosaurs	
19			"Greenhouse effect"	
20a			**Even after the thicker dust had settled**	Clause as theme
21a			These	
22b			*	
22			These two climatic *changes*	
23			It is possible	
24			This *fossilised* shell	
25			Other reptiles such as crocodiles, snakes and lizards.	
26			Many other groups	

clause as theme: bold; *grammatical metaphor: italicised*

A clause by clause analysis of thematic development in Prehistoric Life is provided in Table 4.5.6. This text combines the use of hyperthemes (that is the subheadings in clauses 12 and 19) and β clauses as theme (clause 2a, 5a, 20a) to organise the text by signalling new sections of the text. 'Heavy' themes, (topical themes with embedded nominal groups) are also used. The first two β clause themes in Prehistoric Life concern the time scale of the extinction:

2a *When dinosaurs became extinct at the end of the Cretaceous period 65 million years ago*

5a *Because these extinctions happened 65 million years ago*

These two themes begin paragraphs 1 and 2 of the text, and could perhaps be said to signal the beginning of two new stages in the argument. The next new stage in the argument (impact theory) is signalled firstly by the subheading 12 *Meteorite impact*, and also by the external adversative conjunction in clause 13a which refers back to the gradualism theory found in clauses 6 and 7.

The beginning of the penultimate paragraph is once again marked by a subheading and a β clause theme, which does not however start a new phase in the argument, as it merely continues the speculation concerning the likely atmospheric conditions consequent upon impact:

20 *Even after the thicker dust had settled*

The central part of the text under the heading *Meteorite impact*, (clause 12 - 18) contains three topical themes with embedded clauses or phrases:

14 *A huge crater [[that could have been caused by such an impact]]*

15 *Rocks [[all over the world laid down at that time]]*

17 *Many of the plants, [both on land and in the sea.]*

Use of β clauses as theme and 'heavy' themes indicates that Prehistoric Life may well be a slightly more adult/complex text than the other books for children in that its thematic development through marked themes is similar to more complex texts. This greater level of sophistication is supported in its greater use of causal identifying processes than the other three texts for children.

4.5.2.2 Nominalisation and embedding in the books for children

In this section I consider the use of nominalisation and embedding in the books for children.

Nominalisation in the books for children

There are not many nominalisations in any of the children's books. However, Prehistoric Life and Tyrannosauraus rex appear to have a similar number to Trefil and Hazen, the textbook for non-science students.

Table 4.5.7 Nominalisation in the books for children

All about Dinosaurs	Nil
DK Picturepedia	[24]*reaction*
Prehistoric Life	[5a, 6b, 13, 22]*extinction*, [7d]*eruptions*, [8]*fallout*
Tyrannosauraus rex	[13c]*collision*, [19b]*arguments*, [25]*warming*, [26]*radiation*, [28a]*explosion*

Embedding in the books for children

Embedding in these four children's books falls into two main categories: embedded questions and, the most common kind of embedding in these texts, embedded clauses that add to the specificity of what is said.

Examples of embedded questions are:

[3]*We are not sure [[why this happened]].* (from All about Dinosaurs)
[37]*But no single theory can explain [[what really happened]].* (from DK Picturepedia)

Examples of embedded clauses adding greater specificity to what is said are:

[6b]*dinosaurs, and other groups [[that became extinct]], were becoming less numerous* (from Prehistoric Life)
[9a]*Only the little scuttling mammals, [[that had been hiding underground when disaster struck]], emerged from their holes* (from Tyrannosauraus rex)

Table 4.5.8 Embedding in the books for children

	All about Dinosaurs	DK Picturepedia	Prehistoric Life	T Rex	Total
Questions	2	3	1	0	6
Packaging information as facts	1	1	0	0	2
Increasing the specificity of what is said	1	7	11	8	27
Instances of embedding	4	11	12	8	35

4.5.2.3 Passivisation in the books for children

All uses of the passive in DK Picturepedia, Prehistoric Life and Tyrannosauraus rex are recoverable either from context or the agent is present in object position. DK Picturepedia has more instances of passivisation than the other three books. Once again I equate this text with Trefil and Hazen, the textbook aimed at non-scientists, which only has three instances of passivisation. I regard this use of passivisation, particularly in DK Picturepedia as one of the ways that children's books show signs of being early versions of textbooks. The relatively low use of passives is not coupled with a foregrounding of individual scientists (as it is in the popular texts). Instead, three of the books - All about Dinosaurs, DK Picturepedia and Prehistoric Life - attribute ideas to the generic '*scientists*'. Once again this shows similarities with the textbook for non-scientists by Trefil and Hazen.

Table 4.5.9 Instances of passivisation in the books for children

	Total	Agent present in object position	Agent obscured	Agent recoverable from context
All about Dinosaurs	0			
DK Picturepedia	5	2		3
Prehistoric Life	2			2
Tyrannosauraus rex	2			2

4.5.2.4 Conjunctive relations in the books for children

I begin this section with a clause by clause analysis of conjunctive relations in Prehistoric Life. As in All about Dinosaurs and DK Picturepedia, there are no internal conjunctions in Prehistoric Life. A reason for this could be the shortness of the texts making this explicit text organisation unnecessary. External conjunctions are largely temporal (outlining the timeframe in which the extinctions happened), causal (outlining why certain possible extinction scenarios would have caused extinction), and adversative (more than one possible explanation).

Of the four books for children, Tyrannosauraus rex is the only one where the principle conjunctive means of structuring the text is through conjunctions of addition, contributing to its being a more spoken text than the other three texts. The other three texts use adversative, addition, causal and temporal conjunctions.

Table 4.5.10 Conjunctive relations in Prehistoric Life

Internal conjunctive relations: rhetorical structure	clause	External: real world conjunctive relations	
	2a	Temporal: simultaneous	When
	2b	Extension: addition	so did
	3	Extension: adversative	But
	4	(elaboration: exemplifying)	(for example)
	5a	Causal-conditional	Because
	5b		
	6		
	7b		
	7c	Causal-conditional: reason	perhaps because
	7d	Causal-conditional: reason	and because
	8		
	9		
	10		
	11		
	12		
	13	Extension: adversative	But
	14	(Elaboration: exemplifying)	(as evidence)
	15		
	16a		
	16b		
	17	(causal-conditional: reason)	(on account of this)
	18	Temporal: following	Then
	19		
	20a	Temporal: following	Even after
	20b	Extension: addition	and
	20c		
	21a		
	21b	(causal conditional)	(thus)
	22		
	23		
	24		
	25		
	26		

Note: Clause 8-11 and clause 24-26 are captions of illustrations

To summarise, in the four books for children, external conjunctive relations predominate as in all other texts considered except Raup and Sepkoski. Temporal, causal and additive and adversative conjunctions are common. An unusual feature in the books for children compared to all other texts is that causal relations are realised conjunctively (which Halliday regards as congruently) rather than clausally in identifying or mental processes as is common in the other texts. Another unusual feature is that temporal conjunctions in the children's texts relate to the time of the dinosaurs rather than to the present time as they do for example in the Scientific American and Time articles, both narratives of research.

4.5.2.5 Summary and overview of Mode in the books for children

My analysis of Mode thus indicates two points of interest in the organisation of these texts. The first of these is features that contribute to these texts being more literal and more congruent in their realisation of meaning than the other texts in the study. The second is features that suggest similarities with textbooks. Examples of features that contribute to these texts being more literal and more congruent in their realisation of meaning are the dearth of passivisation and nominalisation and the fact that causal relations are more often realised conjunctively than in other texts. Temporal conjunctions relate to the time of the dinosaurs rather than to present time as in the other texts in the study. In one of the texts pictures are a structuring device with the text accompanying each picture.

Examples of features that indicate similarities with textbooks are firstly that there is about the same amount of nominalisation in these texts as in Trefil and Hazen the textbook for non-scientists. Similarly, incidence of use of the passive is similar to the amount found in Trefil and Hazen. Neither nominalisation nor passivisation is used to conceal the agent. By contrast with the popular texts the comparative dearth of passivisation is not matched by foregrounding of individual scientists: those found are all generic as in textbooks.

Other aspects of organisation of the texts are thematic development and embedding. The method of development in four texts involves hyperthemes in the form of subheadings. As in the other texts embedded clauses that add to the specificity of what is said are the most common function of embedding although embedded questions that serve to engage the interest of the readers are also found.

4.5.3 Tenor in the books for children

Tenor refers to the roles of the reader and writer of a text and the interaction between them. Science books for children are written by adults for children with the aim of informing. In section 4.5.5 below, I argue that the introduction to one of the texts (DK Picturepedia), projects the reader as a middle-class child whose highly literate parents will guide him/her in reading and interpreting the text. In this section I report on my investigation of the illustrations in the text, as well as the categories of contact, affect and status, hedging, and evaluation.

4.5.3.1 Illustrations in the books for children

Illustrations have an ideational function (information-giving) as well as an interpersonal function. In the case of DK Picturepedia (appendix page 40) they even have a structuring function as each paragraph is associated with and illustrated by a diagram. Nevertheless, I feel that the interpersonal function is the most important function served by illustrations in books for children. They attract the interest of the reader and show solidarity with them. I have therefore chosen to consider illustrations under tenor.

The Prehistoric Life text (see foldout in appendix page 46) is on a double page and forms a chapter entitled "*What went wrong*". The left or Given page (Kress and van Leeuwen 1996) shows three images supporting the Impact Hypothesis. In bottom left position, i.e. most Given and Real (Kress and van Leeuwen 1996), is a photograph of a real impact crater. This is shown from a high oblique angle, not entirely top-down/objective, but showing the perspective of the landscape. Interestingly, in every text which shows an impact crater, the image is sited at the bottom (Real) and often at the left (Given). It appears that being real, photographs of real craters, which are well accepted to have been caused by extraterrestrial impact, these craters are invariably viewed as Real, solid and earthly.

To the right of the impact crater (somewhat Newer) and also in Real position is a map of the Gulf of Mexico, the proposed impact site for this particular extinction. Maps are Offer images; they offer "objective dispassionate knowledge, ostensibly free of emotive involvement and subjectivity" (Kress and van Leeuwen 1996:126). This presents something essentially uncertain and speculative as objective and possessed of a fair degree of certainty.

Above the map in Ideal position is the meteorite in the act of hitting the Earth The resulting explosion is represented by concentric circles emanating from the impact. This image is naturalistically drawn but, being drawn, has less truth value than the map, photograph of an impact crater and photograph of an Ammonite fossil of the right hand page. It is represented as an Ideal model/possibility of what happened. This Ideal position for the asteroid/meteorite/comet hitting the Earth or exploding is found in two of the other texts for children: All about Dinosaurs and Tyrannosauraus rex. DK Picturepedia places the asteroid speeding towards Earth and actually hitting Earth in bottom Real position and also chooses images with more photographic truth value to represent this.

On the right or New page is a photograph of an Ammonite fossil in bottom Real position. It is photographed from above and thus represented as an objective scientific specimen: a real piece of evidence. The inset block in top Ideal position is a classificatory structure with "What survived" on the left (Given) and "What disappeared" on the right (New). The labelled attributes of this structure represent the important classes of each group: amphibians, insects, mammals and reptiles who survived, and pterosaurs, ammonites, plesiosaurs and dinosaurs who did not. This is similar to the image in DK Picturepedia that shows what survived.

As we would expect in a book for children, all four of the texts have a number of very colourful illustrations. Some of these are very naturalistic paintings/drawings, while others are photographs, the form with the highest current cultural truth-value. In a similar way to the Liopleurodon image in the Mail and Guardian, which was a photograph of a long-gone scene, one of the texts for children (DK Picturepedia), produces an illustration of an asteroid hitting earth that has high truth value in that it looks like a photograph.

All four books illustrate the impact and dinosaurs; three illustrate the survivors and three illustrate an impact crater. In all three cases the impact craters are in high oblique angle, not entirely top-down (objective) as in the Scientific American image of an impact crater. All four texts favour the impact hypothesis, and this is visually reinforced by the salience and number of the impact illustrations. On the other hand, three of the texts choose to illustrate alternative hypotheses (mammals eating dinosaur eggs, caterpillars eating the vegetation, poisonous plants.) Thus although the text is does not favour these explanations, the illustrations, like the text, give them some space as possibilities.

4.5.3.2 Contact, affect and status in the books for children

In this section I consider Contact, Affect and Status in Duff, three categories which Gerot (1995:104) uses to illuminate the interpersonal metafunction.

Contact in books for children

Contact refers to writer's solidarity with readers (Gerot 1995:104). Solidarity is indicated in a number of ways in the four books for children that I analysed. I will consider Prehistoric Life first, and then make some general remarks about the books for children as a whole. The title of Prehistoric Life, (*What went wrong?*), is a question, which engages the readers in the problem of what caused the extinction. The illustrations of the text also express solidarity with a child reader. So too does the occasional vivid and dramatic language: [8]*huge impact*; [15]*enormous impact*; [23]*...their final end, announced by the fiery glow of a huge meteor streaking across the sky.*

In general, the books for children are clearly scientific texts and features which they share with the other genres in the study are a tendency to be rather impersonal, and the technical language used in three of the children's books. However, solidarity with the child readers is shown in a number of ways:

The child readers' interest is engaged through questions (All about Dinosaurs, Prehistoric Life) exclamations (DK Picturepedia), joking (DK Picturepedia), illustrations (all four books), and vivid and dramatic language (Prehistoric Life). Tyrannosauraus rex also uses two types of text, narrative and factual report, in order perhaps to appeal to children who like one or other text type. In two of the texts (All about Dinosaurs, DK Picturepedia) solidarity is shown through use of **we** (reader, writer and scientists). This identifies the reader with scientists as a group. The writers use these features to mitigate the difficulties involved in reading impersonal and technical texts. From this perspective they are inducting readers into scientific genres such as textbooks. Use and definition of technical terms such as 'greenhouse effect' and 'plankton' introduces the reader to such terminology and thus includes them as members of the scientist group.

The writers of these books are writing for children who like facts, and who have had some exposure to factual writing. The assumption is often made that the narrative form is easier and more 'naturally' accessed by readers but as Martin (1989) has argued this is likely to be because of our greater exposure to the narrative form. Nevertheless it is more likely that middle class children will be exposed to books of the sort analysed here. That the authors of the books project their readers as middle class children with highly literate parents who value information for their children is, I argue, clear from the editors' introduction to DK Picturepedia discussed in section 4.5.4 below. The similarities between these books and textbooks indicates that childhood exposure to books of this sort may be an advantage to children later in their education.

Affect in the books for children

Affect refers to 'positive or negative attitude of the writers to the readers and what they are talking about' (Gerot 1995:104). The children's books project a positive attitude to science and scientists (who collocate with most of the mental verbs and thus do most of the thinking). The physical evidence of rocks, craters, minerals and fossils is evoked to indicate that quantitative evidence is what guides science. However science is not cut and dried as there are various theories portrayed in all four texts. Particularly interesting features that indicate affect in the four texts are an astonished exclamation in DK Picturepedia ([16]*What a hole*!), an amused exclamation in DK Picturepedia ([34]*Some are more unlikely than others*!), and attitudinal lexis in Tyrannosauraus rex ([14b]*the effect of the impact is devastating;* [28a]*an unimaginable explosion;* [19a]*All of the alternative theories have their weak points*)

Status in the books for children

Status refers to how the writer includes the reader (Gerot 1995:104). In Prehistoric Life the writer is an adult and the intended readers are children, but there is no indication of any inequality of status between writer and reader.

There is some technical language, what Martin (1993:230) refers to as distillation:

[2b]*tiny forms of sea life (plankton)*

[20c]*the atmosphere would have contained a lot of finer dust ...*[21a]*These would have caused what scientists call a "greenhouse effect"*

There are some nominalisations:

[2a]*became extinct* becomes [5a]*extinctions*

Although few, these instances of technical language and nominalisation indicate that the writer is directing the text at children who are on their way to acquiring this register/ literacy. There is no reference to either reader or writer, making this text like the textbooks.

For the most part the books for children belong to the genre information report: as in the textbooks the reader is an authority supplying information. Apart from this the writer does not patronise or talk down to the reader, in spite of the fact that the reader is a child and the writers are adults. In one case the writer includes a narrative text, presumably to engage the reader in what is usually considered as an easier form. Two of the books include the reader in the texts and as I argue, as scientists, by using *we*. Two of the texts include the reader by asking questions, and one by use of exclamations which serve to engage the child in the text. All the texts use many colourful illustrations to engage the interest of the children.

4.5.3.3 Hedging in the books for children

Prehistoric Life contains a lot of reliability hedges, which, appears to be the most prominent type of hedge in this genre. Writers use reliability hedges to indicate that there is some doubt about the proposition under discussion.

Table 4.5.11 Hedging in Prehistoric Life

	Hedge	**Reason for hedge (after Hyland)**
5b	no one knows	Reliability hedge
6a	some scientists think that	writer-oriented/ reliability hedge
7a	They believe that...	writer oriented hedge
7b	the climate may have become cooler ...	Reliability hedge
7c	perhaps because the seas were ...	Reliability hedge
8	The huge impact would have caused	Reliability hedge
9	The Yucatan area may have been the site	Reliability hedge
11	The Cretaceous meteorite could have made	Reliability hedge
14	A huge crater that could have been caused	Reliability hedge
15	...unusual minerals which could have come	Reliability hedge
16a	This debris could have darkened	Reliability hedge
17	many of the plants... would have died	Reliability hedge
20c	...the atmosphere would still have contained	Reliability hedge
21a	These would have caused ...	Reliability hedge
21a	...what scientists call	writer-oriented hedge
22	These... changes would have caused ...	Reliability hedge
23	It is possible that	Reliability hedge

Table 4.5.12 shows that the most common form of hedge in books for children is reliability hedges. This suggests that the major motivation for tentativeness is the writer's wish to share with the reader his/her impression of how reliable the information is. This is one way that books for children are similar to textbooks. In both genres, the writer is trying to

provide the best explanation of the topic that he/she is able to give, and to indicate to readers the extent of his/her own confidence in the information provided.

Table 4.5.12 Summary of hedges in the books for Children

	Reliability	Attribute	Writer-oriented	Reader-oriented*	Total
All about Dinosaurs	6	1		4	11
DK Picturepedia	13	1	3	1	17
Prehistoric Life	14.5		2.5	1	18
Tyrannosauraus rex	5	3			8

*These are questions, which I regard as including and showing solidarity with readers, and thus as reader-oriented hedges.

4.5.3.4 Evaluation in the books for children

Table 4.5.13 below shows evaluation in Prehistoric Life in terms of value and status (Hunston1993, 1994). The writer starts the text by stating what is known: that the dinosaurs became extinct, how long ago, and which living things, in contrast, survived. The writer then moves on to the two major extinction theories. An analysis of status indicates that in Prehistoric Life, as in All about Dinosaurs and DK Picturepedia, the gradualism theory (rated possible) is less likely that the impact theory (rated possible to probable with some elements of certainty). Thus this analysis allows us to say what was not obvious before, that the impact theory is favoured by the writer. In terms of value, both the gradualism and impact theories are positively evaluated, both having the ability to explain the extinction in a useful (gradualism) or reasonable (impact) way. The map photographs and illustrations play a large part in adding value to the text. They are a kind of evidence for what is said in the text, taking the place played by data in a research article.

Interestingly, in the case of two clauses, it is the embedded nominal groups that contain the modal verbs, with the process of the clause - the main finite verb - unmodalised:

[14]*A huge crater that could have been caused by such an impact has been found near the north coast of Mexico.*

[15]*Rocks all over the world laid down at that time contain unusual minerals which could have come from the material of the meteorite,*

In these two cases the clause itself is certain, but the embedded clause is not.

All four books evaluate the impact hypothesis more positively than they do other theories. This is achieved both in the text and in the illustrations. In the books for children the

Table 4.5.13 Evaluation in Prehistoric Life

Clause	Activity	Source	Modification	Certainty	value
1	question	writer		unknown	
2a	narrate event	accepted knowledge		certain	
2b	narrate event	accepted knowledge		certain	**known events/ facts**
3	state fact	writer		certain	
4	state fact	writer		certain	
5a	narrate event	accepted knowledge		certain	
5c	hypothesise	writer/accepted knowledge	no one knows	unknown	
6a	project				
6b	hypothesise	scientists	some scientists think	possible	**hypothesis**
7a	project				
7b	hypothesise	scientists	they believe	possible	*useful*
7c	hypothesise	scientists	perhaps	possible	
7d	hypothesise	scientists		possible	
8*	hypothesise	writer/ scientists	would have caused	probable	**drawing** believable
9*	hypothesise	accepted knowledge	may have been the site	possible	**map** *useful*
10*	describe photograph	writer		certain	**photograph** *useful*
11*	hypothesise	writer	could have made	possible	
12					
13	hypothesis	writer/ scientists	there is evidence	probable	**hypothesis**
14	state fact	writer/ scientists	could have been caused	possible known	*reasonable*
15	state fact	writer/ scientists	could have come from	known possible	*reasonable*
16a	hypothesise	writer	could have darkened	possible	*useful*
16b	hypothesise	writer		possible	
17	hypothesise	writer/ scientists	would have died	probable	
18	state fact	writer/ scientists		certain	
19					
20a	narrate event	writer/ scientists		probable	*useful*
20b	narrate event	writer/ scientists		probable	
20c	hypothesise	writer/ scientists	would have contained	probable	
21a	hypothesise	scientists	would have caused	probable	
21b	state fact	scientists		probable	
22	hypothesise	writer/ scientists	would have caused	probable	
23	hypothesise	writer	possible	possible	
24*	state fact photograph	accepted knowledge		known	*believable*
25*	state fact illustrations	accepted knowledge		known	
26*	state fact illustrations	accepted knowledge		known	believable

* Captions of illustrations

illustrations serve as evidence, and add value to the theories they illustrate. Three of the books (DK Picturepedia, Prehistoric Life, and Tyrannosauraus rex) illustrate the impact hypothesis in half or more than half of their illustrations. Thus although none of the books present this as the only possibility, through diagrams, subtle modality and mental processes, the impact theory becomes the most likely possibility.

Unlike the popular articles, there is no sequential positive and negative evaluation, which gives the popular articles their debate/dialogic structure. Thus, evaluation appears in the books for children to serve the purpose of conveying the writer's real opinion – i.e. how likely a particular theory is. By contrast, popular texts allow the writer to appear objective by presenting the opinions of others and allowing these other voices to speak for the writer while subtly evaluating them.

4.5.3.5 Summary and overview of Tenor in the books for children

Although impersonal, the books for children show solidarity with the child readers through the colourful illustrations, questions, exclamations, joking, vivid and dramatic language. In the case of one of the texts (i.e. Tyrannosaurus rex) the information is rehearsed in both factual and narrative form. Solidarity is also shown through use of **we**, which identifies the reader with scientists. The books have a positive attitude to scientists and science. Science is not identified as permanent and incontrovertible (Lemke 1990) and it is clear that this is an area of continuing discovery. As in textbooks, the most common hedges are reliability hedges indicating that the writer wants to give an accurate impression of how reliable the information is. Evaluation in the children's books, both overt and implied, and including the pictures, appears to function to indicate the writer's opinion of how likely a certain theory is. The impact hypothesis is evaluated far more positively than the other theories. This is confirmed by the salience and number of the impact illustrations.

4.5.4 Summary and overview of Register in the books for children

The books for children show similarities with textbooks. An example is that reference to human participants is generic indicating the facts and ideas are more important than the people who suggested them. Elements of textual organisation such as passivisation and nominalisation show similarities in amount and function to the simplest of the three textbooks, Trefil and Hazen the textbook for non-scientists. For example, as in Trefil and

Hazen, these elements do not conceal agency. Another similarity is that the most common hedges in both genres are reliability hedges, indicating that sharing a sense of the reliability of the information is more important than shielding the writer from challenges to what is said or showing solidarity politeness to readers. These similarities with textbooks suggest that childhood exposure to books of this sort is a great advantage to children later in their education.

A difference from textbooks is that the children's books are literal rather than abstract and meaning is more likely to be congruently realised than in any of the other texts. The children's books have a greater focus on dinosaurs and physical real world happenings. This is reflected in the fact that most processes are material and concern dinosaurs, impact and its climatic effects. Causal relations are more likely to be realised conjunctively than in any of other texts. Diagrams are large and colourful and are used as a structuring device for the text. They also add value to what they illustrate.

4.5.5 Genre in the books for children

Three of the four texts for children in this study are information reports. The fourth text (i.e. Tyrannosaurus rex) consists of four sections, the central two of which are information reports while the first and last sections are narratives/recounts. This makes this text very unusual in the genre, which very seldom structures texts as narratives. As in textbooks, information report and explanation are the norm.

The four texts analysed show a variation in terms of their expectations of the ability of the child readers to cope with a purely factual text. Factual texts are sometimes viewed as more difficult and less accessible than narratives (e.g. Lemke 1990). Martin (1985) maintains however that factual texts are not intrinsically more difficult than narrative – merely less familiar because people in general have less exposure to them. This argument would not view including narrative sections in what is essentially a factual text as beneficial to the child readers. Tyrannosauraus rex stands on the side of the argument that views factual texts as intrinsically more difficult than narrative, and children as needing to be encouraged and inducted into reading factual material by the inclusion of what is assumed to be the more familiar narrative form. Tyrannosauraus rex thus provides an initial narrative followed by a factual section By contrast, the other three texts are completely factual. They make fewer concessions to the contention that factual material may be more difficult than narrative. Chief among the concessions they do make are simple themes, simple nominal groups, and few identifying processes.

All four texts contain a glossary and an index. Both All about Dinosaurs and DK Picturepedia start with double contents pages with the 'chapter' headings beneath a picture illustrating each 'chapter'. The book is thus accessible to beginning readers. These books present themselves as reference books for children: from the very young to children of about ten years old. But they are not dry or boring. All four are colourfully illustrated. Pictures are primary, and even a child who cannot read at all would enjoy them. It is interesting to note that, for example in the contents pages and in the text/'chapter' in DK Picturepedia and to a lesser extent Tyrannosauraus rex, pictures are a structuring device in these texts for children. The reader chooses what part to read and in what order based partly on the pictures. As noted below, in DK Picturepedia this obviates the need for internal conjunctions, whose text organising and content-anticipating role is filled by pictures

DK Picturepedia, in particular is characterised by the editors as a "picturepedia", and the first page of the book contains a 'Note to Parents' reproduced on page 44 of the appendix.

In this 'Note to Parents' the text explicitly points out (to the readers' parents) the reference nature of the text. This book is part of a series designed to initiate children into accessing factual information. The editors envisage the readers as belonging to families who are likely to read the book with the child. The projected reader is a member of a family that enjoys and values activities like posing questions and answering these by consulting factual reference works. They are leisured, well off (they can afford to buy these books), and the adult members of the family already have the 'look it up' literacy into which these books are designed to initiate the child reader. In short these are children of middle class families from Heath's (1986) "Maintown".

4.5.6 The ideology of science books for children

Ideologically science books for children have similarities with textbooks in that individual scientists do not feature and generic scientists are much less important than the facts they uncover. In the textbooks science involves a process of scientists uncovering pre-existing facts. Because they are more literal and focused on happenings at the time of the dinosaurs rather than scientists' theories on or research into these happenings, the books for children seem to be one step closer to the facts than are the textbooks.

Table 4.5.14 Average number of human participants/1000 words in the texts in the study

Research article	textbooks	Popular texts	Books for children
4.4	12.6	25.6	12.2

Table 4.5.14 shows that the average number of human participants in the books for children is the same as in the textbooks, and all are generic. The difference is that the textbooks on the one hand are abstract, with focus on ideas and research with the people who thought of the ideas or did the research deliberately removed through passivisation and nominalisation. The texts for children by contrast are not abstract but literal. They are about the facts of what happened to the dinosaurs. The circumstances in the texts indicate a focus on the time of the dinosaurs. Who discovered these facts is irrelevant. The books for children are thus even closer to the facts than are textbooks. Books for children are less impersonal than the textbooks because 'we', the reader and writer, feature in them and are aligned and identified with scientists.

The books for children are to some extent like textbooks for young children. Differences between textbooks and science books for children are apparent in the inclusion of the readers in books for children, and the greater attempt to make the books attractive to the readers through many large colourful illustrations. Another difference is in the motivation of the readers of textbooks and books for children. Readers of textbooks have been assigned the textbook reading as part of a course of study; child readers of science books read them purely for pleasure. In this they are more like the popular science articles.

4.5.7 Summary

Science books for children are very similar to textbooks in terms of register, genre and ideology. Differences at the level of register are that, in terms of Mode, as might be expected in texts for children, there is little nominalisation, embedding or passivisation. At the level of tenor the texts for children make a greater attempt to engage the child readers in the text, with some use of questions, personal language, including identification of the child reader with scientists, and many colourful illustrations. Ideational content of the texts for children is focused on dinosaurs, a very popular topic amongst children, rather than mass extinctions, or theories or research about them. The texts for children are more literal than the textbooks, which, being for university students, are fairly abstract. Once again this is explainable in terms of the age of the readers.

The genre of science texts for children is for the most part information report, a common genre in textbooks. Unusually for the genre, one of the texts for children rehearses the information first in a narrative section, presumably in an attempt to make the text more accessible to children. Ideologically, science texts for children are also similar to textbooks in that they regard facts as pre-existing their discovery. I have characterised books for children as having an even greater focus on 'the facts' than textbooks in that the textbooks in this study, being for tertiary students focus on either theories (what scientists think) or research (what scientists have done). Textbooks are thus at a further remove from the facts of what happened during the Cretaceous mass extinction than are books for children. Once again it is possible that this is partly a function of the intended age of the readers of the texts.

4.6 Comparison of the genres analysed in this chapter

4.6.0 Introduction

This study examines texts in four different genres: the research article genre, the textbook, popular articles and finally, science books for children. In sections 4.1 to 4.5, I have reported on my analysis of an exemplary text in each of the four genres, and have referred to other texts in each genre where necessary, except in the case of the research article genre. Because researchers have done more work on the research article genre, I have analysed only one text from this genre. To indicate the variation in the popular science genre, sections 4.3 and 4.4 provide analyses of texts from this genre. In the present section, I summarise and compare the analyses of the four different genres. In doing so, I draw not only on the analyses of the exemplary texts that I have reported on in sections 4.1 to 4 5, but also on the other texts I have referred to in these sections. The texts concerned are:

Genre	**Texts**
Research article	Raup and Sepkoski
Textbooks	Duff (first year textbook)
	McGhee (for advanced students)
	Trefil and Hazen (for non-science students)
Popular Texts	Scientific American,
	Time,
	Mail and Guardian
Texts for Children	Prehistoric Life,
	All about Dinosaurs,
	DK Picturepedia,
	Tyrannosaurus rex

4.6.1 Field in the texts in the study

In selecting texts that are all on the same topic, Field is the feature that I have attempted to keep constant in this study. Inevitably, there are differences, not only between genres, but between the different texts within each genre. Features in which there is variation are human participants and the kinds of processes most prevalent in each genre.

4.6.1.1 Human participants

The research article and the textbooks for first year students and graduate students are highly impersonal and thus, in the value system of science (Latour and Woolgar 1979), 'objective'. This effect is achieved through use of few human participants in the research article and first year textbook and through mention of human participants in their very limited role as writers of research articles in McGhee. The paucity of human participants in Raup and Sepkoski, Duff, and Trefil and Hazen, and the fact that human participants in McGhee do not appear in major clauses indicates that human participants is not what these texts are about. Human participants are incidental here to facts. Trefil and Hazen, like Duff and McGhee, mentions some generic scientists (facts being more important than who discovered them in textbooks) but is also similar to the popular texts in mentioning the Alvarezes as personalities [[13]the father and son team of Walter Alvarez (a geologist) and Luis Alvarez (a nobel laureate in physics)]. The books for children are like the textbooks in that the only human participants are generic scientists. Like the textbooks, the books for children are not about scientists, but rather about the facts of what happened.

An interesting comparison between popular texts, research articles and textbooks is who is given a voice, and whether that voice reflects their written or spoken utterances.

Research articles privilege the written and specifically published voices of other scientists. Ivanic and Simpson (1992) characterise this limitation to published sources of what can be regarded as legitimate knowledge as a feature of academic discourse. Textbooks, although they cite some published works, are more commonly 'peopled' only by generic representatives of the discourse community (e.g. 'Some palaeontologists' in Duff) or by unmentioned researchers who have been omitted from the text by use of the passive. (An example from Duff is: [11]Much attention **has been paid** to the Cretaceous/Tertiary (K/T) boundary.) The researchers are present but in a very ghostly form. By contrast, the Scientific American and Time texts foreground researchers. They are about researchers, what they think and say and how they engage in their research. Writers scaffold their argument on the ideas and utterances of researchers, thereby giving what they say objectivity (it is apparently the researchers rather than the writers themselves who are responsible for what is said) and also giving what is said the authority of science.

Time, in particular, projects a very positive image of scientists as humorous and friendly, although, in the eccentricity of their pursuits and the religious authority they are invested with, are also projected as 'other'. The Mail and Guardian article also projects an image of scientists as 'other' but here it is in an almost sinister way. Scientists are positioned as generic so we are distanced from them. They are not real people as in Time and Scientific American but are represented as a recalcitrant and unreasonable group, whose ideas can be humorously dismissed. This reflects the varying audiences of the three articles. The audience is projected as scientists in the case of Scientific American (so scientists are not portrayed as 'other'), non-scientists who equate science with progress in the case of Time, and non-scientists who equate science with polluting technology and illegitimate power in the case of the Mail and Guardian. What is very prominent also, particularly in the extract from Time, is that it is not only written published sources that are given voice, but also interviews and conference presentations. An example from the Time article of an interview as a source is: [40a]*Besides,* [40b]*he asked,* [40a]*why should the mammals have survived any Cretaceous catastrophe*? Clauses 50-53 of the Time article contain an example of conference proceedings as a source.

Table 4.6.1 Human Participants in the texts in the study

	R & S	Duff	McGhee	T & H	Scientific American	Time	M & G	Children's books P Life	AAD	DK	Trex
Participants/ 1000 words	4.4	7.4	19.6	10.7	18.8	33.4	24.4	10	26	13	0
Major/minor	Major	major	Minor	Major	Major (+ minor)	Major	Major	Major			
generic/ specific	Spec.	generic	Specific (generic)	generic	specific	Spec.	Generic	Generic			
? Human participants personalised				✓	✓	✓					

In summary, research article and textbooks achieve objectivity through removal of people. Texts for children are similar (as in the textbooks the average number of human participants per 1000 words is 13). However in two of the texts for children the readers are included as '*we*', identifying the child readers with scientists. The average number of human participants per 1000 words in the popular texts is 27. In two of the popular texts these are specific, making these texts about real scientists and what they say. The popular texts do not remove people from the account and achieve objectivity by attributing ideas and saying to these scientists.

4.6.1.2 Participants, processes and circumstances

Although the texts were chosen so that the Field would be the same in each, there are nevertheless differences between what is foregrounded in each text, and what the text is about in each case. Raup and Sepkoski, the research article, is not about dinosaurs or what happened to them. It is about statistical methods to prove the theory that extinction has been periodic rather than gradual. By contrast with the popular articles, people are removed from the account by use of the passive.

In the textbooks, focus is once again not on dinosaurs. Instead the focus is theories: catastrophism vs gradualism (Duff, McGhee and Trefil and Hazen), stratigraphic, fossil and chemical evidence for the theories (McGhee) as well as what happened during the Cretaceous extinction (Trefil and Hazen). In the three textbooks we see a range. On the one end of the range in the three textbooks is the textbook for non-science students (Trefil and Hazen) which focuses on what happened at the end of the Cretaceous, with a minor focus on the light this sheds on the rate of evolution. Between the two extremes in the range is the textbook for first year geology students (Duff) which focuses on development of theories of evolution and the role of the fossil record in this development. It draws students into the culture of the discipline by showing how the theoretical framework of the discipline has developed. At the other end of the range is the textbook for advanced geology students which takes impact as a given and provides an in-depth look at the evidence for impact.

In the popular texts, focus is on people rather than theories or on what happened to the dinosaurs. In the Scientific American and Time articles focus is on the researchers, while in the Mail and Guardian article focus in on the reader and writer and their experience of the theories of palaeontologists, with a secondary focus on what happened to the dinosaurs (Mail and Guardian). Scientific American focuses on researchers, their methods, their theories and how these differ from the methods and theories of other researchers. In Time focus is on the researchers and what they do to collect their data (the endearingly eccentric activities they engage in). The differences between researchers' theories, although mentioned, are of minor importance.

In the books for children focus is on what happened to the dinosaurs during the Cretaceaous extinction (of particular importance in Tyrannosuarus rex) and the theories that 'we' and scientists have about how it happened. Two of the texts (Prehistoric Life and *DK Picturepedia*) suggest evidence for the impact theory. These books for children can be characterised as textbooks for young children with people ('we' and scientists) brought into the picture, as in the popular texts, to encourage reader involvement.

Table 4.6.2: What each text is about

Raup and Sepkoski	What was done to test the notion of periodicity in mass extinctions, what was proved statistically, and what this implies.
Duff	The development of theories of how evolution has progressed and the role of mass extinction in this. Ideas are the main actors in the text
McGhee	What researchers have thought about a meteorite cause for the K/T and other mass extinctions, and what evidence they have produced for this.
Trefil and Hazen	Mainly about what happened in the K-T mass extinction and also some information on the light this sheds on the rate of extinction.
Scientific American	A narrative of knowledge claims: about researchers and their research into possible periodicity in mass extinction and possible causes for periodicity.
Time	A narrative of research indicating how scientists go about their research into what caused the extinction of the Dinosaurs.
Mail and Guardian	What caused the extinction of the dinosaurs at the end of the Cretaceous – one cause or a number of causes?
Books for children	Dinosaurs and what happened to cause them to become extinct at the end of the Cretaceous: a number of theories are suggested.

As can be seen from Table 4.6.2 above, three areas of focus are discernible: researcher actions and evidence, the nature of extinction, and physical meanings to do with the asteroid, the climate, and living things.

Four of the texts – Raup and Sepkoski, McGhee, Scientific American and Time focus on researcher actions and evidence. They do this in different ways. For example Raup and Sepkoski never mention the researchers (themselves) and achieve the account through agentless passives. McGhee mentions the researchers mainly in citations, and the Scientific American article, and to an even greater extent the Time article, make the researchers and their actions the focus.

The second focus, the nature of extinction, is found in Duff, Trefil and Hazen, the Scientific American article and the Mail and Guardian article. Most of these texts realise this focus through identifying processes; Duff however uses material processes in this discussion.

The third focus, physical meanings to do with the asteroid, the climate, and living things, is found to a greater extent in texts for non-specialists, most prominently the texts for children, but also the Mail and Guardian article, the Time article, Trefil and Hazen, and in the embedded clauses of McGhee. The texts for children and the Mail and Guardian extract are the only texts to focus on dinosaurs.

Scientists are the agents of mental and verbal processes in all texts, with some reference to the reader in McGhee, the Mail and Guardian and the texts for children. As Table 4.6.3 below indicates, material processes are numerous in all texts in the study. This is particularly true of Duff (which treats ideas like things, and uses material processes to express meanings that usually would be realised in relational processes) and the books for children (which express particularly literal and real world meanings). Relational processes are numerous in most of the texts, except Duff, the article from Time, and one of the books for children. A large number of relational processes is particularly noticeable in Raup and Sepkoski, in McGhee, in Trefil and Hazen, and the Scientific American article. Attributive processes are more prominent than identifying processes in the books for children, indicating their concern to provide vivid descriptions of things rather than define them.

Table 4.6.3: Processes in the texts in the study

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	*Scientific American*	Time	*Mail & Guardian*	Children's books			
								Prehistoric Life	A A Dinosaurs	DK	T Rex
material	**16 (23%)**	**14 (52%)**	**15 (21%)**	10 (30%)	**14 (34%)**	**49 (48%)**	10 (41%	**41%**	**58%**	**52%**	**68%**
mental	6	5 (19%)	5	4	3	14 (14%)	**5 (21%)**	8%	16%	18%	
verbal	4	2	8 (11%)	3	6 (15%)	11 (11%)					
identifying	**22 (31%)**	5 (19%)	**15 (21%)**	9 (27%)	10 (24%	12 (12%)	5 (21%)	15%	5%	11%	6%
attributive	**16 (23%)**		**25 (36%)**	6 (18%)	**8 (20%)**	10 (11%)	2	**32%**	**21%**	16%	11%
behavioural	5		1			4					
existential	1	1	1	1		3	2	3%		2%	15%
total	70	29	70	33	41	103	24	34	19	44	47

Table 4.6.4 Circumstances in the texts in the study

	R & S	Duff	McGhee	Trefil & Hazen	Scientific American	Time	Mail & Guardian	Children's books			
								Prehistoric Life	All about Dinosaurs	DK	T Rex
Extent: duration	2	**4 20%**	6 **22%**		1	5 9%	**4 33%**	1		2	2 10%
Location: place	2	**3 15%**	9 **33%**	2	**8 38%**	**25 45%**	**4 33%**	**3 27%**	1	9 **36%**	**11 52%**
Location: time	2	2	2	9 **47%**	**3** 14%	**7** 13%	2 17%	**4 36%**	**3 50%**	**7 28%**	1
Manner	3	**4 20%**	3 11%	**4 21%**	**3 14%**	13 **24%**	1	1	1	**5 20%**	**5 24%**
Cause		1		1	1			**2 18%**	1	1	2 10%
Contingency		1	1	1	1						
Accompaniment	1	**4 20%**	1			2	2 17%			1	
Role			3 (11%)		1	1					
Matter		1	1	2	4 (19%)	2					
angle			1			1					
	10	20	27	19	21	56	12	11	6	25	21

Circumstances

It is not obvious that there are differences between genres in terms of circumstances. It appears that discussion of this field requires locating what is happening in time and place, making known the duration of extinction and relating how the extinction took place and how findings were made (manner). Circumstances of time include present day and geological time in different texts. Circumstances of place include stratigraphy, locations at which research was done, location in space, and abstract place such as journal articles. Also important are circumstances of duration (how long the extinction took) and circumstances of manner.

4.6.1.3 Summary and overview of Field in the texts in the study

The focus of the research article, Raup and Sepkoski, is the authors' own research and what this implies. This is a narrower focus than any of the other texts. Focus in the other texts varies from the very wide-ranging and abstract consideration of theories of the rate of evolution over the last two centuries (Duff and Trefil and Hazen), to a narrower focus on the range of evidence for asteroid impact (McGhee and Scientific American), to how researchers go about research into the end Cretaceous extinction (Time), to the more literal focus on dinosaurs and the end Cretaceous extinction (the books for children, Trefil and Hazen and the Mail and Guardian article).

Different kinds of abstraction are displayed in Raup and Sepkoski compared to the textbooks. Raup and Sepkoski is abstract in the sense that readers must interpret it using knowledge of statistics external to the text. The textbooks, particularly Duff and McGhee are abstract in the sense that certain types of information are packaged into embedded clauses and are thus less easily challenged by readers

Participation of humans in the texts marks a major distinction between the research article, the textbooks and the children's texts on the one hand and the popular texts on the other. The research article removes human participants for complex reasons. They remove other researchers for reasons of politeness (to avoid disagreeing with them) while they remove themselves because to be accepted as a fact their knowledge claim must be removed from human agency – it must be a reflection of nature, not what they think. Textbooks and books for children remove human participants because the facts and ideas are more important than the people who first proposed them. In both research articles and textbooks impersonality is a way to signal objectivity. By contrast, in two of the three popular texts, researchers are central to the account and objectivity is signalled journalistically by quoting these researchers so the writer appears not to be responsible for what is said.

4.6.2 Mode in the texts in the study

The elements of mode which are most revealing are those most usually investigated in relation to science texts: passivisation and nominalisation. In the research article and textbooks it is clear that these features are used to conceal agency and that this contributes to establishing objectivity in these texts. In the popular texts by contrast there is very little passivisation and nominalisation does not conceal agency.

4.6.2.1 Theme

Table 4.6.5 below summarises the method of development of the various texts and indicates the function served in each case. (Two ticks indicates that this feature is particularly prominent). The texts show varied methods of thematic development, with the most common marked themes in these texts being adjuncts, especially of time and place, and 'heavy' themes.

The greatest evidence of the writer directing the interpretation of the reader is found in three of the texts in particular: Raup and Sepkoski, the Scientific American article, and the Mail and Guardian article. In Raup and Sepkoski, which is a highly impersonal text in general, the writers use interpersonal themes combined with textual themes and β clauses as theme to track their argument and make it clear and credible to the reader. These marked themes support Myers' (1989) contention that research articles, although apparently objective, actually have a persuasive function in that they must convince the research community in the person of the reader to accept their knowledge claim.

The author of the Scientific American article also wishes to appear objective, and in the value system of journalism this means giving "both" sides of the story. This the article does, but by skilful use of marked themes amongst other things, the writer signals to the reader that one side of the story is more credible than the other.

Table 4.6.5 Theme in the texts in the study

	β clauses	Adjuncts	interpersonal	Textual	Heavy theme	Preposed attributives	subtitles	Maintain theme	Progression of theme	Method of development
Raup & Sepkoski	✓		✓	✓						β clauses as theme. interpersonal and textual themes track the progression of the argument. These marked themes signal what the writers view as NB.
Duff		✓			✓					Marked topical themes (heavy themes and adjuncts) and contrastive textual themes indicate to reader lack of consensus between the voices on this topic
McGhee	✓	✓	✓	✓	✓ ✓			✓	✓	By use of alternating sections of marked themes maintenance of theme, and progression of theme, the writer provides a detailed description of research in the area
Trefil & Hazen		✓						✓	✓	Maintenance and progression of theme provides non-scientist readers with an overview. Adjuncts as marked theme do not change framework but signal examples. Impression of greater consensus on the matter than in other texts.
Scientific American		✓			✓					Each paragraph has a heavy theme in 1st clause or adjunct of time/place in 2nd clause or both. This signals to the reader what is NB and how to interpret the text. The writer guides reader interpretation closely giving more credibility to one of two voices in the debate in the text.
Time		✓ ✓			✓	✓				Introduction uses adjuncts of time & place to set the scene. Bridging section uses summative themes defining introductory sketches as 'quests'. Rest of text uses adjuncts, heavy themes, and preposed attributives to make biographical material thematic and give a narrative tone.
Mail and Guardian				✓	✓			✓		Sections of maintenance of theme and marked themes (heavy themes and adjuncts) function to set up expectations in the reader. These expectations are then undercut/contradicted by use of textual themes indicating contrast.
Books for children							✓			An organisational device common to the four children's books in the study is the use of subtitles as hypertheme.

The Mail and Guardian article is unusual in this selection of texts in that an appearance of objectivity is less important than is amusing the reader. In achieving this, the writer uses, among other devices, short sections maintaining the theme, followed by sections of marked theme. These set up expectations in the reader, but are followed by textual themes indicating contrast, which undercut and 'disappoint' the expectation. The reader is skilfully led to feel that the expectations have been raised and disappointed by scientists/palaeontologists, who are represented by the text as largely wrong-thinking with far-fetched ideas.

4.6.2.2 Nominalisation and embedding

Nominalisation and embedding are both features of more written texts. Nominalisation makes a verb adverb or adjective into a noun, while embedding extends the nominal group.

Nominalisation in the texts in the study

The general impression of Duff as a very abstract text, and of Raup and Sepkoski, and McGhee as also pretty abstract and hard to process is borne out by the count in Table 4.6.6 of the number of different nominalisations in the different texts. Trefil and Hazen is has an unusually low number of nominalisations in the context of the other two textbooks, and this is presumably because the writers are writing for non-science students and thus want to make their text as accessible and non-technical as possible. The number of nominalisations in Trefil and Hazen is comparable to the number in the texts for children, and is lower than the number in the three popular texts. This implies that the authors of Trefil and Hazen regard their readers as unlikely to tolerate even the number of nominalisations acceptable to the (educated) readers of newspapers and news-magazines.

Table 4.6.6 Use of Nominalisation in the texts in the study

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	Mail & Guardian	Children's books P Life	AAD	DK	T rex
Number of words in text	900	540	560	560	900	1675	327	482	155	400	462
Number of different nominalisations	39	30	25	4	27	33	6	3	0	1	5
Different nominalisations per 1000 words	43	56	45	7	30	20	18	6	-	3	11
Number of nominalised mental and verbal processes	5	3	3	2	10	5	2	0	0	0	1
Technical terms	✓	✓	✓	✓	✓	✓	-	✓	-	-	✓
Cause and effect argument and keeping reasoning in same clause	✓	✓	✓		✓	✓					
Mention of agency avoided	✓	✓									

The Scientific American article is shown by Table 4.6.6 to have a significantly larger number of nominalisations than the other two popular texts, perhaps a reflection of the greater knowledge of science of the readership of Scientific American. The readers of the Mail and Guardian and Time, by contrast, are not expected to be scientists.

Nominalisations function as technical terms and in efficient argument in all of the texts in the study. According to my analysis only Raup and Sepkoski, and Duff make significant use of nominalisation to avoid mention of agency. Only the Scientific American article, characterised in my analysis as a narrative of rival knowledge claims, has a significant number of nominalised mental/verbal processes.

Embedding in the texts in the study

Table 4.6.7, which follows, shows that a number of functions are served by embedding in the texts in the study. The function of increasing the level of specificity of what is said is found in all the texts in the study. A second quite general function is that of packaging central propositions into facts. These are often imported from other texts and are often subjected to evaluative commentary sited in the ranking clause. This function is found in Raup and Sepkoski, the three textbooks, and to a limited extent in two of the children's texts. [This is one of the ways that the children's texts show similarities to textbooks.] Related to this function are intertextual embedded clauses that are not facts, which are also subjected to evaluative commentary sited in the ranking clause. Embedding serves this function in Raup and Sepkoski, the three textbooks and Scientific American. In two of the textbooks, Duff and McGhee, this intertextual material serves to increase the abstraction of the texts. This is because information on a particular topic (evolution in Duff and real world information in McGhee) is sited in embedded clauses so the text is

Table 4.6.7 Functions served by embedding in the different texts in this study.

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	Mail & Guardian	Children's books
Increases level of specificity	✓	✓	✓	✓	✓	✓	✓	✓
Propositions packaged as facts	✓	✓	✓	✓				✓
Intertextual information		✓	✓	✓	✓			
Increases level of abstraction		✓	✓					
embedded Evaluative comment						✓	✓	
Narrative detail						✓		
Embedded questions								✓

able to function on more than one level. Unusually in this selection of texts, evaluative comment is sometimes sited in embedded clauses in Time and the Mail and Guardian.

Only in Time, the most narrative of all the texts in this study, is narrative detail embedded. Embedded questions are a feature of the children's texts only. Here I believe they serve an affective role, functioning to engage the interest of the readers.

4.6.2.3 Passivisation

The passive is widely used only in the research article, Raup and Sepkoski, and in two of the three textbooks, (in Duff, and in McGhee). Use of the passive is complex only in Raup and Sepkoski. Here it serves the four functions of (1) showing politeness/deference to the reader, (2) implying that certain ideas are widely accepted by not attributing them to a specific agent, (3) thematising Given information or (4) foregrounding the goal as more central to meaning than the agent. It is the third and fourth functions that are central in all the other texts. Textbooks and children's books most often foreground the goal as more central to meaning. The agent may be present or may be implied as the generic 'scientists'. This is one way in which we can view the children's books as early versions of textbooks. In general the three popular science texts use passives only to thematise Given information. In the Mail and Guardian passives are found almost exclusively in embedded clauses.

4.6.2.4 Conjunctive relations

As indicated in Table 4.6.8 below, a number of differences in conjunctive relations are apparent in the texts in the study. These are: whether internal conjunctions are common or not in the texts, how cause is realised in the texts, the use of adversative conjunctions, and the time period referred to by the temporal conjunctions. The research article, Raup and Sepkoski is the only text in the study to use many internal conjunctions. I have explained this in terms of the persuasive function of research articles and the authors' subsequent need to direct the argument explicitly.

There is variation in how cause is realised, with the more 'written' texts – Raup and Sepkoski, the three textbooks and the most serious of the three popular texts, the Scientific American article – relying on identifying processes, and to a lesser extent mental and verbal processes to realise cause. By contrast, the less serious popular texts, the Time and Mail and Guardian articles realise cause mainly through mental processes.

The texts for children are the only ones where cause is realised congruently. They alone use causal conjunctions (and also mental processes) to realise cause.

Table 4.6.8: Kinds of conjunctions in the different texts in the study

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	Mail & Guardian	Children's books
Internal conjunctions present?	Yes. Function in persuasion							
How is cause realised?	Cause realised in Identifying and to a lesser extent mental/verbal processes					Cause realised in mental processes		though conjunction mental & a few identifying processes
Conditional conjunctions?	✓✓ in speculative section			✓				
Adversative conjunctions?	few	✓✓	✓✓	✓	✓✓		✓	✓
Temporal conjunctions?					✓✓ narrative – relates to present time			✓ relates to time of dinosaurs
Spatial conjunctions?					✓✓			

Considering that different explanations for the extinction of the dinosaurs are being discussed in these texts, it is not surprising to find that adversative conjunctions are very common in the texts. The only texts where this is not the case are Raup and Sepkoski and the Time article. In Raup and Sepkoski, the authors avoid stressing differences. They do this firstly for reasons of politeness, to avoid offending other researchers by openly disagreeing with them, and secondly to increase their own credibility, by creating an appearance of continuity with previous research. In the Time article different theories are put forward but there is no attempt to argue between them or come to a conclusion about which is correct, thus there are few adversative conjunctions.

The popular texts and texts for children use a lot of temporal conjunctions. However, in the popular texts, which are narratives of when research has been conducted, the temporal conjunctions refer to the present time By contrast, in the children's texts, which are more concerned with what happened sixty-five million years ago in the time of the dinosaurs, temporal conjunctions point the reader to the time of the dinosaurs.

4.6.2.5 Lexical density in the texts in the study

Halliday 1989:62) characterises written text as grammatically simple but lexically dense. Lexical density is a measure of the lexical complexity of a text. A lexical item is distinguished from a grammatical item which include determiners, pronouns, prepositions, conjunctions and some adverbs and finite verbs (Halliday 1989: 61). It is calculated by dividing the number of lexical items in a text by the number of ranking clauses. Another measure of lexical density (Gerot 1995:75; Jenkins 1992) is calculated by dividing the number of lexical items by the number of words in the text. The table below indicates that the textbooks have a higher number of lexical items per clause than any of the other genres, while, as expected, on average the children's books have far fewer. Interestingly the number of lexical items as a proportion of the total number of words remains pretty constant across the texts in the study. This means that the textbooks have the longest clauses, while the children's books have the shortest clauses.

Tbale 4.6.9: Lexical density in the texts in the study.

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	Mail & Guardian	Children's books P Life	AAD	DK	T rex
Number of words in text	916	540	565	560	900	472	327	482	155	418	448
Number of lexical items	543	284	296	290	413	254	184	259	81	229	228
Number of clauses	70	27	27	34	41	32	26	33	17	50	48
Lexical items/clause	7.8	10.5	11.0	8.53	10.1	7.94	7.8	7.85	4.76	4.58	4.75
Lexical items/total words	.59	.53	.52	.52	.46	.54	.56	.54	.52	.55	.51

4.6.2.6 Summary and overview of Mode in the texts in the study

Raup and Sepkoski and two of the popular texts, Scientific American and the Mail and Guardian article, are the texts showing most evidence of having been organised with a view to directing the readers' interpretation, largely through use of marked theme and conjunction. Raup and Sepkoski uses interpersonal, textual and β clauses as theme to track the argument and make it clear and credible to the reader. Scientific American uses textual themes, conjunctions of contrast and adjuncts as theme combined with nominalised mental and verbal processes to signal the progression of a narrative of research and guide the reader to view one 'side of the argument' as more convincing. The Mail and Guardian article uses theme to set up expectations which are then undercut and 'disappointed' by the use of adversative conjunctions. Besides this humorous device, the Mail and Guardian also uses nominalisation (to omit agency that is then supplied in brackets) and clausal ellipsis to serve its humorous ends.

Duff, the exemplary textbook analysed, is interesting in that it uses theme and conjunction to indicate past and present 'opposing voices' on the topic. However, because ideas in textbooks are more important than who first put them forward, the people behind the voices are generic, and are never made explicit.

The texts for children reflect their greater literalness and simplicity in being organised largely through hyperthemes (subheadings) and in the dearth of passivisation and nominalisation, and cause realised conjunctively rather than in identifying proceses. The amount of nominalisation and passivisation in the texts for children is comparable to the amount in the textbook for non-science students.

4.6.3 Tenor in the texts in the study

This section compares the texts in the study in terms of Tenor, the interpersonal meanings in a text. Contact (solidarity with the reader), Affect (positive or negative attitude to readers and subject matter), Status (how the writer includes the reader), Hedging (expressions of tentativeness), Evaluation and illustrations in the texts in the study are considered. Once again, I consider illustrations under Tenor because although illustrations contribute to ideational meaning and can even have a structuring role, they make a major contribution to interpersonal meaning particularly in the texts for children where they are most prominent.

4.6.3.1 Contact

Contact refers to solidarity of the writer with the reader (Gerot 1995:104). The table below indicates that the first year and advanced textbooks show solidarity with readers in ways that are similar to the research article (Raup and Sepkoski); in these three cases solidarity with the reader is indicated by formality (impersonal tone, nominalisation, technical language and passivisation). The advanced textbook also refers to research articles as does Raup and Sepkoski. The difference between research article on the one hand and these two textbooks on the other is that the research article shows more solidarity politeness (reader-oriented hedges). These three texts are for researchers in the field in the case of the research article and students who are being inducted into the field in the case of the textbooks.

Table 4.6.10: Summary of contact in the texts in the study

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	*Mail & Guardian*	Children's books
Impersonal	√√	√√	√√	√				
Nominalisation	√√	√√	√√					
Passivisation	√√	√√	√√					
Technical terms	√√	√√	√√	√	√			A few
Intertextual references	Research articles	Popular science book	Research articles		RAs, newspapers	interviews RAs		
Projected readers	researchers in the field Science discourse community	1st year geology student	advanced students	Non-science students	Scientists in other fields	educated Non-scientist	Educated Non-scientist	Middle class children
Solidarity with readers	Formality, Reader-oriented hedges	writer initiates reader into debate No interest in scientists as people	formality Cites RAs, detailed discussion of evidence; No interest in scientists as people	Low level of nominalisation + passives technical terms; Interest in scientists as people	Details of statistics and methods; details of argument about research	Narrative, descriptive. reader & writer identified. Scientists 'geeky', eccentric, have religious authority. Joking tone.	Informal (clausal ellipsis); humor (lexis); reader & writer sensible, scientists have silly theories	Reader identified with scientists; Questions, exclamations joking, illustrated, vivid language, narrative & factual
View of science	+	+	+	+	+	+	scientists not objective palaeontology is trivial	+

In terms of solidarity of the writer with the reader, the textbook for non-science students (Trefil and Hazen) shows more similarities with the popular texts than with the other two textbooks. They all have much less nominalisation, passivisation and use fewer technical terms. Like the popular texts Trefil and Hazen treats scientists as personalities ([13]*a Nobel laureate in physics*). The popular texts (particularly the Time and the Mail and Guardian articles) are joking in tone. Being aimed at largely non-scientist audiences, they are the only texts that distance reader and writer from scientists: Time in a positive way and the Mail and Guardian in a negative way. In terms of solidarity of the writer with the reader the books for children are very like the textbooks, but without the formality of nominalisation, passivisation and a lot of technical terms. Like the textbooks they are serious in tone and mostly factual information report in genre. Importantly, like the textbooks, they identify the reader with scientists as a group. They show solidarity with the child readers in a range of ways such as questions, exclamations, vivid language and illustrations.

4.6.3.2 Affect

The research article, the three textbooks and the books for children all signal objectivity through impersonality (and thus, given the cultural context, they signal high truth-value). This is particularly the case in the research article and the textbooks for first year and advanced geology students. These three texts achieve this impersonality through a high level of passivisation and nominalisation. The genre of the textbook and texts for children is information report: the writers are authoritatively offering information. The popular articles by contrast are less impersonal and signal objectivity though more journalistic means – i.e. by couching the writer's arguments as those of other people (researchers in the case of Scientific American and Time articles and the reader/reasonable person in the Mail and Guardian article).

Another signal of objectivity in the research article, textbooks and children's books is the paucity of attitudinal lexis. Only the popular articles have a fair amount of attitudinal lexis, the most being found in of the Mail and Guardian article. The textbooks' authors' only attitudinal lexis is mildly to call the topic interesting, important and stimulating. The popular texts however make it clear which theory they favour through attitudinal lexis (particularly the Mail and Guardian article), giving greater voice/space to the theory they

Table 4.6.11 Affect in the texts in the study

	Raup & Sepkoski	Duff	McGhee	Trefil & Hazen	Scientific American	Time	*Mail & Guardian*	Children's books
How is objectivity signaled?	Impersonality achieved through passivisation & nominalisation, paucity of human participants			Impersonal and factual	Writer couches own arguments as researchers' arguments. Narrative form – reporting on what happened.		Writer couches own arguments as reader's. Humour on topic more NB than objectivity	Impersonal tone
Attitudinal lexis	Very little Mostly subtle. Writers' ideas = plausible, others' ideas = incredible	subject is stimulating	Subject interesting	Subject interesting & important	✓ writer clearly rejects periodicity	✓ writer has enthusiasm & liking for science; favours impact theory	✓✓ more attitudinal lexis than any other text	Amount varies between texts. All texts favour impact.
Attitude to science	Based on rigorous quantitative & statistical methods. Science is an unmarked activity.	objective Theories based on quantitative data	quantitative data enables progress towards facts	Physical evidence enables progress towards factual explanation	Science is controversial Good science is quantitative & unbiased	Science is not boring or dead. It is dynamic & controversial	Palaeontology is trivial	Not cut & dried – various theories. Science based on physical evidence
Attitude to scientists	Positive. Scientists are sincere and well-intentioned. They have their differences based on differences in interpretation of data.				Positive. Scientists: meticulous, devoted, humorous, emotional, eccentric, & have religious authority. exotic locations		Negative. Scientists are petulant, have implausible theories & are not objective	Scientists collocate with mental processes

favour (Scientific American and Time articles) and overtly rejecting the theory they do not favour (Scientific American article).

The textbooks and to an extent the children's books are once again similar to the research article in their attitudes to science and scientists. Science in these texts is based on quantitative methods and is an unmarked activity. Being a scientist is an unmarked occupation and there is no suggestion that scientists are other than sincere and well-intentioned. They do have different theories and these are based on differences in interpretation of data. This reflects the projected scientist readership of these texts. The Scientific American article, also having a scientist readership, is very similar in its attitudes to science and scientists, the only difference being that the controversy between researchers is stressed, as it is in the other popular articles. The Time article portrays science as fascinating while the Mail and Guardian article portrays it as trivial and boring. These two texts have non-scientist readerships and portray scientists as 'other' from the reader and writer. For the writer of the Time article, scientists are meticulous and devoted but also eccentric and possessed of religious authority. The Mail and Guardian article is the only one negative towards science and scientists: scientists foist implausible theories on the public and are subjective. Their differences are based on unreasonable personal preferences.

4.6.3.3 Status

Status refers to how the writer includes the reader (Gerot 1995:104). In the research article the reader represents the research community and is thus more powerful than the writer. In the popular texts there is greater equality between the reader and writer although it is important for the writer to cater to the needs and interests of the readers who have economic power over the writer in that they can choose to buy the publication or not. It is therefore important to include the readers and make them feel recognised. The popular articles do this in a variety of ways. These are: including the reader in fields outside their own field (all three popular texts) endorsing the values of quantitative science (Scientific American), narrative form, enthusiasm for topic (Time) humour (Time and Mail and Guardian) shared negative assessment of science (Mail and Guardian). In the textbooks and books for children the writer is an authority supplying information, while the reader is a relative novice.

Table 4.6.12 Status in the texts in the study

	How does the writer include the reader?
Raup and Sepkoski	Solidarity politeness to the reader; Reader (representing discourse community) is more powerful than the writer. Writer includes reader by sticking to familiar form & conventions of the discourse.
Duff	Reader-writer relationship is authority and expert geologist/novice geologist and student. Includes reader by recommending popular source in enthusiastic terms.
McGhee	Reader-writer relationship: authority and expert geologist/ student and possible future geologist. Includes reader by treating them as those who already know about the topic.
Trefil and Hazen	Relationship between writer and reader is authority and scientist/ non-scientist student evidenced in key terms in bold etc. Readers included by making scientists into interesting personalities: some biographical information is included.
Scientific American	Reader-writer relationship: science journalist/scientists outside the field under discussion. Neither reader nor writer are experts in the field. Narrative includes reader. The text is a means of inclusion of readers outside the field in the findings of the field.
Time	Reader-writer relationship: journalist/educated middle class readers. The reader is included through narrative form, enthusiasm of writer for subject, and colour pictures.
Mail and Guardian	Writer includes reader by assuming that reader and writer are of the same group and scientists are treated flippantly. Writer uses humour and pictures to include reader and assumes a shared negative assessment of science and scientists.
Books for children	Writer is authority supplying information. Writers include reader by use of colourful pictures, reference to '*we*', questions, using exclamations, and using narrative form.

4.6.3.4 Hedging

In Table 4.6.13 below I follow Hyland (1996c) in his categorisation of hedges into:

a) Reader-oriented hedges, which hedge assertiveness and function to get acceptance of claims that are face-threatening because they contradict the claims of other researchers (Myers 1989). Hyland (1996c:446) claims that adherence to discourse norms is also part of this "collegiate deference".

b) Writer-oriented hedges hedge writer commitment. "aim to shield the writer from the consequences of opposition by limiting personal commitment" (Hyland 1996c:443)

c) Accuracy-oriented hedges hedge propositional content and "involve the writer's desire to express propositions with greater precision...and appropriate caution". (Hyland 1996c:440). They are of two types:

- Attribute hedges: "enable writers to distinguish how far results approximate to an idealised state, specifying more precisely the attributes of the phenomena described" (Hyland 1996c:440). Usually 'degree of precision' adverbs.
- Reliability hedges: indicate the writer's confidence in the truth of a proposition... acknowledge subjective uncertainties...motivated by the writer's desire to explicitly convey an assessment of propositional validity" Hyland (1996c:441).

Table 4.6.13 Kinds of hedges in each text

	Raup and Sepkoski					Textbooks			Popular journals			Children's texts			
Hedges	Abstract	*Intro*	*Discussion*	Implications	total	Duff	Trefil & Hazen	McGhee	Scientific American	Mail and Guardian	Time	All About Dinosaurs	DK Picturepedia	Prehistoric Life	T Rex
reader-oriented	1		2 9%	10 45%	13 59%					1 11%		4 36%	1 6%		
writer-oriented		2 9%		2 15%	4 18%	6 66%	6 25%	20 40%	8 47%	1 11%	17 39%		3 17%		
Writer-oriented/ narrative form?											3 7%			2 12%	
attribute							9 38%	2 4%		1 11%	3 7%	1 9%	1 6%		3 38%
reliability		1	3 14%		4 18%	3 33%	9 38%	28 56%	5 29%	6 67%	21 48%	6 55%	13 72%	14 82%	5 63%
? reliability/ reader-oriented				1	1										
? reliability or writer-oriented									4 24%					1 6%	
total	1	3	5		22	9	24	50	17	9	44	11	18	17	8

From Table 4.6.13 it can be concluded that, as Myers (1989) found, reader-oriented hedges are very important in some sections of research articles. Writers of research articles have to show deference to readers, as the readers represent the research community. In particular, writers have to convince the editor and referees of the article that they are not claiming too much. Myers (1989) shows how knowledge claims are cut back by writers of research articles in response to comments by referees.

Textbooks are similar to children's books in that reliability hedges, (which indicate the writer's confidence in the truth of a proposition), are very common in these genres. I explain this in terms of the writers of these genres wishing to communicate to the readers the best approximation to the truth available to them at the moment, including an accurate measure of their uncertainty on the matter. Besides reliability hedges, writer-oriented hedges are also important in textbooks. Two of the textbooks in the study (Duff and Trefil and Hazen) ascribe ideas to generic scientists, a function of the fact that these textbooks are summarising the field. The third textbook, McGhee, cites research articles, presumably for the further reference of the readers who are students more advanced than first year level. The popular articles also have many reliability and writer-oriented hedges. They use writer-oriented hedges to shield themselves and their journal from possible suggestions by readers that they are misrepresenting research etc. It is the researchers to whom ideas are attributed that are responsible for what is said – not the writer. They use reliability hedges to assess how likely what they are talking about – other people's research - is to be true. There appears to be no necessity to mitigate face threatening acts to readers by use of reader-oriented hedges because the vast majority of their readers are not in the field covered in the article and will not find their own research and opinions contradicted there.

The above table shows that in popular journal articles both writer-oriented and reliability hedges are important. Writers of popular journal articles do not have to defer to their readers in the same way that writers of research articles do. Perhaps we could infer that popular journal article writers have a more equal power relationship with their readership. They use writer-oriented hedges to indicate their objectivity and their role in neutrally reporting the ideas and utterances of others. They use reliability hedges to assess how likely what they are talking about – other people's research - is to be true.

4.6.3.5 Evaluation

Evaluation in the textbooks and children's books appears to be more overt than that in the popular texts and the research article. In the textbooks and children's books the source of information is usually the writer or apparently the writer because the writer got the information from unspecified research articles Thus the evaluation appears to come from the writer. The writer of textbooks appears more willing than in other genres to go on record with his/her evaluations. In a paradoxical way this gives their account an appearance of greater honesty because they appear not to be hiding their opinion. By contrast, the source of information in most clauses in the popular articles is other people, whose voices are used by the writers to construct the writer's argument. Thus evaluation appears to come from the other voices. This device lends objectivity to the account. The research article by Raup and Sepkoski avoids negative evaluation firstly for purposes of deference to the scientific community, and secondly out of a desire for their own methods, results and hypotheses to appear in as positive a light as possible.

Sequential negative and positive evaluations are used to structure popular science articles, but not the textbooks, books for children, or the research article. The popular articles in this study use a dialogic/debate structure in which a theory is sequentially positively and negatively evaluated. On the one hand this is a function of the discussion genre employed in many popular articles. In a discussion arguments for and against an issue are presented

(Butt et al 1995:20). However merely labelling the genre as discussion, and defining what a discussion is, does not explain why this genre is chosen in this context and what purposes it serves. I suggest two possible purposes. Firstly, this structure functions in indicating the controversial nature of what is discussed. Controversy and oppositions appear to stimulate the interest of the reader. The second function is an appearance of objectivity on the part of the writer, which is thus achieved differently from the way objectivity is achieved in research articles and textbooks i.e. though impersonality. The dialogic structure in popular articles allows voices external to the article to debate a topic, indirectly presenting the writer's own argument. The writer thus appears to be neutrally reporting what others have said while actually it is the writer that chooses to report what s/he agrees with and it is the writer that structures the article so that his/her own favoured viewpoint is foregrounded and appears correct.

This dialogic structure – the sequential positive and negative evaluation of an idea – is not a feature of the other genres in the study besides the popular texts. Although the textbooks and books for children do have both positive and negative evaluation of a particular theory, this is not a repeated series of positive and negative evaluations. Instead the writer may distinguish two different theories and then give a clear indication of which they consider to be more correct. The purpose of this in both these genres appears to be efficient communication of information the writer considers to be factual. The genre here is information report.

In the extract of the research article examined in the study the authors make very few negative evaluations of ideas they disagree with. In particular no negative evaluations are made of their own methods or results. Because they aim to convince the readers, no purpose would be served in such a negative evaluation. In their introduction Raup and Sepkoski merely juxtapose the gradualism idea with their own favoured idea (periodic catastrophism), without negatively evaluating it, presumably in politeness to supporters of this viewpoint. This may include the majority of the readers/research community.

Raup and Sepkoski negatively evaluate research that they agree with, as not having been rigorous enough in its methods (indicating the need for their own research). The genre of the introduction is discussion, as is the genre of the implications section. In their Implications section Raup and Sepkoski overtly negatively evaluate the option (earthly cause of periodic extinction) that they do not favour. In this highly speculative section, for which they present no evidence, their negative evaluation of the option they do favour (extraterrestrial cause of periodic extinction) is formulaic. From this limited analysis of a single research article, it appears that negative evaluation is avoided for two reasons: politeness to those they disagree with (in the Introduction and Implications sections, both of which are in the Discussion genre), and the necessity to present their own ideas in as positive a light as possible (in their Method, Results and Discussion sections).

4.6.3.6 Illustrations in the texts in the study

The illustrations in Raup and Sepkoski, Duff, McGhee and Scientific American all signal themselves to be as objective as possible. Raup and Sepkoski has a graph, a highly abstract objective form. Duff has a table, also highly abstract and objective. McGhee and the Scientific American text have top-down, objective 'God's-eye view' photographs All the other texts have illustrations that still have high truth-value, but are less objective in some way or other. Trefil and Hazen has a table similar to Duff, except that it is illustrated with coloured drawings, so is less abstract. Illustrations in the Time article have high truth-value, being photographs for the most part, but these are not at all abstract, being of people or recognisable landscapes. One of the two Mail and Guardian illustrations is exaggerated, detracting from its truth-value. The books for children are the least objective in that they are drawings, paintings as well as photographs.

Table 4 6.14 has been organised in terms of the extent to which the illustrations serve to make the text more accessible to readers. As can be seen from the table, the Time article is unusual amongst the texts for adults in having a wide variety of illustrations and photographs. In this text and in the four books for children, the illustrations are very prominent and function to draw the reader into the text. They show solidarity with the reader and cater to the reader's need for a visual element in order to make the text more accessible. For the same reason, the Mail and Guardian article has two large photographs and the single geological time-scale in Trefil and Hazen is very illustrative, with pictures of people and animals in the time-scale.

The books for children are more likely than the other texts to provide an imaginative reconstruction. As has been mentioned above they are more grounded in the time of the dinosaurs. For example, all four children's books, and none of the other texts, depict the actual instant of impact; all show dinosaurs; three depict the alternative theories in action (rodents eating the eggs); one depicts the immediate aftermath of the impact.

Table 4.6.14 What is illustrated in each text in the study

	R & S	Duff	McGhee	*Scientific American*	Trefil & Hazen	*M & G*	Time	Children's books			
								AAD	DK	P Life	T Rex
Geological time scale		✓			✓		✓				
impact								✓	✓	✓	✓
Impact crater				✓			✓		✓	✓	✓
dinosaur					✓	✓	✓	✓	✓	✓	✓
Comet /asteroid							✓		✓		
people					✓		✓✓				
survivors								✓	✓	✓	
other	graph		Moon of Mars				Diagram of model; fossil	rats & eggs	map; rats & eggs; iridium & quartz	Map; fossil.	Rats + eggs; cater pillar; after-math
	less attempt to make text accessible → more attempt to make text accessible										
	Very high objectivity → fairly high objectivity										

The geological time-scale, is very differently depicted in Duff, Trefil and Hazen and Time. In Duff far fewer allowances are made for readers than in the other two texts. The table is highly abstract, not to scale, and contains no colour. In Trefil and Hazen the reader is given an illustrative synopsis of the evolution of life from molecules to humans as the pinnacle of evolution. The time-scale in the Time article is to scale, is a three-dimentsional column, has illustrations of organisms that became extinct at the different intervals and has a joke in the form of a tombstone and flowers for the extinct organisms.

In summary, as Table 4.6.14 reflects, the graph in the research article is a highly objective and inaccessible form, followed by the table in Duff and the photographs in McGhee and Scientific American. By contrast the photographs in Time and Mail and Guardian, and in particular the illustrations in the books for children function to show solidarity with and make the text accessible to the reader.

4.6.3.7 Summary and overview of Tenor in the texts in the study

Comparison of the texts in the study in terms of Tenor proves to be most revealing. Much depends on the projected readership of the different texts. The size of this readership is rather small in the case of the research article, and extremely wide in the case of the Time article, with the other texts in between these. Another parameter is whether reader and writer are identified as scientists or at least as positive towards science and scientists. The readers of the research article, two of the textbooks, and the Scientific American article are identified as scientists; so, to an extent, are the child readers of the books of children. In the case of the third textbook the writers but not the readers are scientists. The writers and readers of the Time article and the Mail and Guardian article are not scientists, but only in the case of the Mail and Guardian article is the writer and assumed reader actually hostile to science and scientists. Yet another parameter is the relative power of reader and writer. In only one case – that of the research article - is the reader, as a representative of the research community, assumed to be more powerful than the writer. The discussions in the popular articles appear to assume an equal relationship between reader and writer, while in the textbooks and books for children the writer is an expert offering information to relative neophytes. All these parameters are reflected in overt evaluation, attitudinal lexis, hedging, and degree of impersonality

4.6.4 Summary and overview of register in the texts in the study

This summary of register across four genres demonstrates that there is no indication of a cline of features in the four genres studied. Instead the genres fall into two groups with the research articles, textbooks and books for children showing many similarities at the level of register, and the popular science texts having greater differences from them.

This summary also indicates that there are fairly marked differences between texts within a genre depending on the projected readership of the text. For example although there are strong similarities between two of the textbooks, McGhee and Duff (both aimed at geology students), these two texts display fewer similarities with the textbook for non-science students, Trefil and Hazen. Similarly, although there are many similarities between the Time and Scientific American articles (which both assume an audience positive about science), the assumption of reader hostility to science of the Mail and Guardian article makes for fewer similarities with the other two popular articles.

Nevertheless, despite within-genre differences, it is possible to make some generalisations. There are great similarities at the level of register between the research article and textbook genres. Besides interpersonal differences based on power relations between readers and writers, differences between the two genres are largely at the level of genre (context of culture) which I discuss below. There are also many similarities between texts for children and textbooks, if we allow for the difference in age of the intended readers. Differences are at the level of tenor, with the books for children being more engaging and making greater attempt to include the readers in the text. The popular science texts are distinctly different from the other three genres in two related ways. The first is the large number of human participants in the popular texts and the lack of features (such as passivisation) used in the other texts to achieve impersonality. Secondly, the popular texts are structured through alternate positive and negative evaluation as dialogues/debates, with the human participants, (the authorities on which the journalists writers of the articles rely), being active in the dialogue. I give this greater attention in my discussion of Ideology below.

4.6.5 Genre in the texts in the study

Genre is what Thompson (1996:36) calls 'register plus purpose...what the interactants are doing through language'. In each of the texts in this study, the organisation of the text reflects the writer's purpose and has been chosen to achieve that purpose. The research article's purpose is to get the writer's knowledge claims recognised as fact. Textbooks summarise the information that has been endorsed as fact by the research community, for the purpose of instructing neophyte scientists in these accepted facts. Two of the popular articles in the study function to inform the reader while the other popular article's main aim is to amuse the reader. The texts for children aim both to amuse and inform.

All sections of research articles serve the purpose of getting readers to accept the knowledge claims of the article. The Introduction situates the research within already accepted previous work and tries to show how it is continuous with previous work. The Method section shows how what the researchers did matches the requirements of quantitative science. The Results try to convince the readers of the significance of the research, while the Discussion tries to convince the readers of the explicatory power and expectedness of the results.

To achieve the purpose of instructing new scientists, textbooks are structured as a range of different factual genres, especially information report, explanation, procedure and discussion. Genre is one important way that textbooks in this study differ from research articles.

In terms of genre, the texts for children are surprisingly similar to the textbooks in spite of the age difference of the projected readers. The texts for children in this study all fall into the genre of information report, although one of the texts for children rehearses the information first in a narrative section. This suggests that this text views narrative as likely to make the factual content of the text more accessible to the child reader. Some of concessions made by the other texts for children to the fact that their readers are children are simple nominal groups, few identifying processes and many colourful illustrations.

The popular articles in the study fall into two different media genres: issues report and opinion piece. The Scientific American and Time articles are issues reports on the latest developments in science. Issues reports, White (1997:102) tells us, aim to inform the reader on the discoveries of some authorised source such as ... a scientific researcher". To achieve this purpose, the writer structures his/her own argument as a discussion between opposing opinions held by the authorised sources on the matter. The writer attributes arguments, ideas and utterances to the many human participants and then uses alternate positive and negative evaluation to construct the impression of a dialogue between two sides of an argument. This gives the impression of objectivity, as the writer appears merely to be reporting the ideas of various scientific authorities. The Mail and Guardian article is an opinion piece in which the writer's main aim is to amuse the reader while also providing some information. To achieve his purpose of amusing the reader, the writer uses informal language, clausal ellipsis, and thematic development that builds up 'expectations' in the reader and then 'disappoints' them. Finally, some of what is amusing in this text is based on the writer's assumption that the reader shares his cynical attitude to scientists and dinosaurs. By stressing the unreliability of his own 'authorised sources' the author of the Mail and Guardian takes on himself the authority usually afforded to a professional expert in journalism, and thus jokingly undermines the conventions of journalism.

4.6.6 Ideology in the texts in the study

In this section I synthesise the ideologies about science evident in the texts in the study as well as audience and power relations. As regards the ideologies about science, I consider first what constitutes a fact, then the ideology of objectivity, and, finally, some negative ideologies about science reflected in two of the texts.

4.6.6.1 What is a fact?

In Chapter 2 I discussed Latour and Woolgar's (1979) contention that a proposition put forward in a research article becomes fact only once it is accepted by the research community and is widely treated as a fact by being cited unproblematically in new research articles. Following from this we can view a research article as a bid for a proposition/ knowledge claim to be accepted as fact. Popular articles report on these bids and on challenges to such bids. Textbooks gather together all propositions that have been given the stamp of fact by being accepted by the research community.

Thus we can say that research articles, textbooks and popular journal articles have different relationships with facts. If we regard facts as propositions that have been accepted by the research community, textbooks deal almost entirely in facts. They summarise non-new information that originates from research articles whose claims have been accepted by the research community and thus have achieved the status of fact. By contrast both research articles and popular articles put forward new information that has not yet achieved the status of fact as it has not yet been accepted by the research community. The research article writer's motive is to get his/her knowledge claim accepted, and the popular article writer's purpose is to convey news of new research to readers. But the attitude to this new information of the two genres differs. Research articles present their new information as much as possible as fact. They do this by removal of people, by indicating how their knowledge claims are consistent with propositions already accepted as fact (Introduction section), by showing how meticulously the research was performed (Method) and by showing how reliable their results are and how well they fit the theory (Discussion). By contrast, popular articles have nothing to be gained from representing as fact propositions not yet accepted by the research community. Instead the writer distances him/herself from these new propositions by reporting that someone else has put forward the proposition. Thus they do not treat the proposition as fact but rather as someone else's claim.

4.6.6.2 How objectivity is established in the texts in the study

In science, as in many other fields, propositions become established as fact only if they appear to be based on objective observation rather than the subjective desire for something to be true. The means of establishing objectivity in research articles is through making the text as impersonal as possible. As is universal in research articles, in the Method and Discussion sections of Raup and Sepkoski the research is performed impersonally, with the researchers suppressed by nominalisation, and use of the passive with omission of the agent. As Myers (1989) has shown, personal language admits that what is said is subjective and limited to the writer. An example of such personal language is found in Raup and Sepkoski's speculative [30b]*we favour extraterrestrial causes.* There is thus an attempt to remove ideas from person, time and place in order to establish them as facts. Removal of people is not entirely possible in research articles as the work is necessarily attached to the authors.

Textbooks in my study take removal of people even further than the research article. There are close to as few human participants as in the research article, but in addition almost all are generic. A high level of passivisation and nominalisation contribute to impersonality of the text. In section 4.2 I argue that textbooks reify the fact. They contain a summary of all facts that have been endorsed by the research community as fact. Myers (1989) has pointed out that individual researchers are much less important than is the community in research articles, and textbooks take this even further with individual researchers much less important than their ideas. Individual researchers are almost entirely suppressed, and their work achieves that seamless continuity with the work of other researchers that the Introduction section of research articles strives for. However, in the controversial area of the end-Cretaceous mass extinction, in spite of the generic facelessness of human participants in textbooks, there is no indication that consensus has been reached on the topic. This lack of consensus is clear even in the texts for children. Thus where there is no consensus or broad endorsement of the facts, it is not the case that science is represented as 'established permanent fact' (Lemke 1990). However, in my experience, it is unusual that ideas that have not been broadly endorsed by the research community should be included in textbooks. It may be the case that the large amount of research that has been done on this topic over the last twenty-five years, and its high profile in the popular press make it necessary to mention the topic in first year textbooks. Alternatively, the mention in textbooks may be an indication of the increasing approach to factual status of 'the Alvarez hypothesis' (an extraterrestrial cause for the end Cretaceous mass extinction).

As in the textbooks people are generic in science books for children. In this way the books for children also participate in the ideology of science as objective.

The popular texts in the study establish objectivity not by removal of people, but by peopling the text with many human participants – scientific authorities on what is being discussed - and attributing what is said to them. The writer thus appears to be reporting objectively the ideas and opinions of others, while in fact the writer is actually able to use the words and ideas of others to construct his/her own argument. This is achieved in the three texts in the study through alternate positive and negative evaluation strengthening the impression of a dialogue. Thus there is the appearance of objectivity only. The Mail and Guardian article, falling as it does into the opinion piece genre, is the only text in the study in which amusing the reader is more important than objectivity. Because of this, this text has a good deal of attitudinal lexis, which functions to portray dinosaurs as a subject as boring and overworked and to display scientists as a subjective group who have put forward many unbelievable theories merely because of their own individual preferences.

4.6.6.3 Negative ideologies of science

In most of the texts in this study the writer is identified as a scientist. This is true of the research article, and textbooks. It is implied of the writers of the texts for children. The writer of the Scientific American article is likely to be a science journalist, not a practising research scientist, but likely to have a very strong background in science. It is only in the Time and Mail and Guardian articles that the writers distance themselves and the readers from scientists, and of them only can we infer that they do not identify themselves as scientists. Similarly, only in the Time and Mail and Guardian texts is the projected reader a non-scientist. This is signalled fairly mildly in the Time article in the characterisation of scientists as a group apart from the group formed by writer and readers. This scientist group has almost religious authority ([9]quest, [3]like a seer divining entrails, [58]Eyes turned heavenward) on the one hand, but a certain 'geekiness' on the other ([5]scurry around in the unheated dome, [52a]intricate statistical gymnastics). The text thus contributes to two powerful myths about scientists: science as authoritative (Lemke 1990) and science as the province of 'geeks' – highly intelligent but eccentric. Both of these myths serve to position science as outside the province of most readers.

The Mail and Guardian article goes further than this in positioning of scientists as 'Other'. Academics and palaeontologists are treated flippantly in that they "naturally prefer" a simple explanation, and even "insist there is only one explanation (namely their own)" Some suspect that speculation on the fate of the dinosaurs is "[1b]another source of trivialisation of their subject” – as if there are many sources of trivialisation of palaeontology; we are told what “[10a]most right-thinking palaeontologists” think – with the implication that a number of palaeontologists can be dismissed as wrong-thinking. Their theories are humorous: ‘[3]hardly a week goes by’ without their coming up with new theories for “[3]zapping the dinosaurs” by “[4]death by volcanic eruption” etc. Scientists have foisted these implausible theories on the public ([6]we, [8b]you). This indicates that the writer subscribes to the ideology of scientists as unreliable, self-serving and subjective: somewhat akin to the “Mr Hyde” figure. Dinosaurs are also very flippantly treated and characterised as boring, indicating participation in the popular conception of science as boring, which I contend must contribute to it being more difficult to learn.

4.6.6.4 Audience in the texts in the study

The function of a research article is to persuade readers to accept the knowledge claim of the writers. To do so the research article must conform to the ideology of science to the extent that it must be impersonal and must also show deference to the community. This involves the writer in the difficulty of being impersonal while being persuasive (which is usually achieved subjectively in most genres). The writer uses solidarity politeness, subtle attitudinal lexis and non-lexical evaluation to achieve the persuasion. Textbooks by contrast are not persuasive.

By contrast with research articles that persuade readers to accept their knowledge claims, and textbooks that summarise knowledge claims that have been accepted, popular articles function to tell readers the news about science. This news concerns new findings that do not yet have acceptance by the research community and thus the sanction of fact. Evidential challenges to findings are also news, particularly in the Scientific American article but also in Time. The Mail and Guardian article is also about challenges to theories, and represents most scientists as guided by their own preferences with only some being ‘right-thinking’.

Myers (1989) notes that research articles have a dual audience of what he calls an esoteric group (other researchers in the same field) and exoteric group (readers not active in the discipline but who take an interest in the research). In chapter 2 I reported on Garcés-Conejos' and Sánchez-Macarro's (1998) finding of an equivalent dual audience in popularisations. They found that these writers still show deference to the esoteric community (i.e. other researchers in the same field). However Garcés-Conejos and

Sánchez-Macarro's (1998) study examined long articles written by the original researchers. In the news articles I analyse in this study by contrast I have found no evidence of the kind of deference that would indicate that the writers are also addressing the esoteric community (i.e. researchers in the field that is the subject of the article). The Scientific American article for example twice characterises Raup and Sepkoski as wrong. In none of the popular articles is there any reader-oriented hedging indicating that the writers do not anticipate that the readers will be 'offended' by what is said by having their own or their preferred ideas contradicted.

In textbooks there is also a dual audience: the academics who select the textbook to prescribe for the course they teach as well as students who are the primary readers of the text. In section 4.2 I argue that the academics appear not to be taken account of because the writer projects a reader who is less powerful and less knowledgeable than him/herself. Nevertheless, first year science textbooks are invariably far too long for all the material in them to be the subject of a year-long course. This indicates that the writer is not only writing for his/her own students and own course, but for the courses and students of other academics in the hopes that they will prescribe the textbook because it contains all or most of the material they intend to cover in their course.

The texts for children also project a dual readership: the child readers and those who buy the books, either the parents who read the book to the child or encourage the child in his/her reading, or the adults in schools and libraries who select the book. It is clear in at least one of the texts for children (DK Picturepedia) that the writers project the readers of the texts as being middle class children with educated parents who read the book with the children and encourage their interest in factual information. As in textbooks, scientists are the generic authority for what is said in books for children.

4.6.6.5 Power relations in the texts in the study

In chapter 4 I distinguished the participants in science texts as reader, writer, and research community, including those researchers involved in the research problem that the text reports on and the wider scientific community. Writers of research articles are much less powerful than the scientific community as a whole. They aim to gain the authority of factual status for their propositions by gaining acceptance for these claims from that section of the research community active in the field. To do this writers of research articles must appear objective, and must show deference not only to the audience of researchers in the immediate field, but also to the wider audience of the scientific community. Writers of textbooks by contrast are more powerful than readers are. In summarising information currently endorsed as fact by the research community, they 'speak for' and have the authority of the research community. Writers of science news articles are journalists writing for one of two audiences. They can be writing for the wider scientific community or they can be writing for non-scientists. In either case researchers involved in the research problem are present in the text as the authority on which the writer draws. They are also the means by which the writer appears objective by quoting an authoritative source (or preferably more than one authoritative source, giving 'both sides' of the story), and thus appear to be merely objectively reporting on the utterances and ideas of others.

4.6.7 Summary

In this chapter I have characterised the genres in the study as falling into two main groups in terms of register: on the one hand research article, textbooks and books for children, and on the other hand popular science articles. The research articles and texts books are characterised by language that is impersonal, highly nominalised, with a high level of passivisation. The purpose of this language is to promote the impression of objectivity and thus, in the ideology of science, high truth-value. The language of the books for children is similarly impersonal (although with some inclusion of the child reader and identification of the reader with scientists), but, corresponding to the youth of the reader this impersonality is not achieved by passivisation and nominalisation. Popular science articles, in contrast to the other three texts are not impersonal, and instead signal objectivity through attributing ideas to the many human participants. They are similar to the research articles and popular articles in having a pretty high level of nominalisation and nominal groups extended through embedding, but, having no necessity to remove people, they have low levels of passivisation.

Although research articles are very similar to textbooks in terms of register, they are very different in terms of genre. Research articles invariably follow the Introduction-Method-Results-Discussion structure, with characteristic variations between the register of these, while textbooks and science books for children are generally made up of various factual genres (in the Australian use of the term), such as information report, explanation, procedure, etc. The popular articles in the study fall into two genres – issues report (more common for popular science articles) and opinion piece. The issues report, like the research article reports on new findings that do not yet have the status of fact in that they are not yet accepted by the research community. The opinion piece differs from all other texts in the study in that objectivity is less important than amusing the reader. It is characterised by much more attitudinal lexis and overt evaluation than the other texts in the study.

At the level of ideology differences between the genres are fairly marked. The research article, which aims to get its propositions accepted by the powerful research community (represented by the reader), shows deference to the reader by the use of reader-oriented hedges. In textbooks, I have argued that the writer, as summariser of facts endorsed by the research community, is the representative of that powerful community, and the reader, a relative newcomer, is in the less powerful position. Popular articles differ ideologically depending on how the writer and reader view science and scientists. Of the three texts in this study one, the Scientific American article is written by a scientist for scientists in fields other than the topic of the article. A second, the Time article, is written by a non-scientist for non-scientists who view science in a positive light, as progress, and scientists as a group apart from the reader and writer. The writer of the third article, from *the* Mail and Guardian, projects himself and the reader as non-scientists who are negative about science viewing it as boring and cynical towards scientists viewing them as motivated by selfish subjective aims. There is some evidence that the projected readership of books for children in the study are middle class children. If this is true, and if we accept the link that I have suggested between textbooks and books for children, it is likely that this is another way that middle class children are advantaged in terms of acquisition of school-based literacy (Heath 1986).

Chapter 5:
Pedagogical Applications of the Comparison of Scientific Genres

5.1 Introduction

In chapter 4 I reported on my intensive examination of exemplary science texts in four genres: research article, textbook, popular science and science for children. I noted that research articles and textbooks share a great deal at the levels of register and ideology, while textbooks and science books for children show considerable similarity at the levels of register, genre and ideology. Popular science texts, on the evidence of the data, show considerable differences from the other three forms in terms of genre and in certain respects in terms of register. Significant among the ideological differences between popular science and academic genres (research articles and textbooks) is the fact that popular articles present scientific findings as provisional rather than as established fact. This chapter is a response to my third research question, namely:

> *What is the pedagogical relevance of an understanding of the register features and the ideological assumptions of the four science genres analysed in chapter 4?*

In this chapter I consider how teachers of scientific literacy could use popular texts and popular genres (section 5.3) To place this in perspective and guard against making recommendations that may, from a different perspective, be pedagogically disadvantageous, I consider first the extent to which research article and textbook literacies are target forms for tertiary and, to a lesser degree, secondary students (section 5.2). After briefly reminding the reader of the differences and similarities between popular and academic genres (section 5.3.1), I describe the academic writing course for science students that I teach, and indicate how I use popular texts in this course (section 5.3.2). As I mentioned in chapter 1, my use of popular texts in the writing course I teach was one of the original motivations for my study. I then move on to consider the advantages and disadvantages to students of using popular texts in learning scientific literacy (Section 5.3.3). In section 5.4 I consider the use of popular science texts by teachers of science, and also reflect on whether importing aspects of popular writing into textbooks is likely to have any value or not. Finally in section 5.5 I consider the extent to which science texts for children are similar to textbooks, and may thus be a preparation for using textbooks in later life.

5.2 Textbooks and research articles as target forms for student writing.

Martin (1993:168) notes that textbooks are the main models of written science for school children. In this section I argue that, at the tertiary level, textbooks can be regarded as models for some of the writing – in particular during exams and some assignments - that undergraduate science students do. The research article, by contrast, cannot be regarded as a model for lab reports, as in my experience undergraduate science students see very few research articles. Much stress is however laid on lab reports in undergraduate courses in the experimental sciences. As Braine (1989) found, 85% of the written tasks assigned to undergraduate science students are lab reports. Because of the similarities between lab reports and research articles, I argue below that the stress on lab reports makes research articles a target form that academic staff would like science students to acquire, and I provide evidence of the guidance given to students towards this form below. To distinguish research articles and textbooks, which I argue are key literacies for science students, I begin this account by summarising the similarities and differences between these two forms in terms of register and genre.

5.2.1 Similarities and differences between research articles and textbooks in terms of register and genre.

In sections 4.1 and 4.2 I suggested that the register of textbooks is similar to that of the research article. In what follows I briefly summarise first these similarities and then the differences between the two genres. Both genres use high levels of nominalisation and technical language, and both employ embedded clauses to extend the nominal group. The research article and two of the textbooks studied employ twice as many relational processes as material processes, and one textbook studied employs material processes to express meanings to do with abstract ideas, which would congruently be expressed in relational processes. Another area of similarity between these two genres is the removal of human participants and wide use of the passive voice, the ultimate function of this in both genres being to establish that what is being said is objective.

In terms of register a difference between the research article and textbook is found in one aspect of the interpersonal metafunction: the reader of the textbook is assumed to be less powerful than the writer, while in the case of the research article, the reader is assumed to be more powerful. The writer of the textbook, I have argued, transmits the information sanctioned as fact by the research community, and thus represents that powerful community. Similarly, the readers of the research article are those who, as a group, have the power to accept or not accept as fact the knowledge claims of the article, and thus they, as Myers (1989) has argued, represent the powerful research community. Thus the reader of the research article and the writer of the textbook acquire their power from the same source: both represent the research community. Another difference between textbooks and research articles is that the research article must propose new information. The textbook by contrast contains nothing new but summarises the received information that has been accepted as fact by the research community. In doing so it reifies the fact, buries the individual, and completes the objectification of the fact by removing it not only from time and place (as in the research article) but from the individual researcher as well. The appearance of information in a textbook is its stamp of having become a fact.

Generically, research articles and textbooks are, of course, very different. Considering genre in the sense of the New Rhetoric studies, it is clear that the common Introduction-Method-Results-Discussion structure of the research article is very different from the structure of the textbook. Considering genre in the sense of the Australian school, I indicated in 4.1.5 that research articles contain discussion, recount and exposition, but that these are likely to be associated with particular sections. By contrast, textbooks are likely to contain a good deal of information report, explanation and procedure, and these are not associated with particular generic sections but rather are used according to the need of the writer and the subject under discussion.

5.2.2 Student writing that approximates research articles and textbooks

Having summarised the differences between research article and textbook in terms of register and genre, I now consider the extent to which the writing of tertiary science students is expected to approximate to these two genres. In chapter 2 I argued that in one important literacy event that science students participate in, namely, examinations, they are expected to produce texts that have many similarities with the writing in textbooks. Genres such as descriptive and explanatory essays, as well as short explanations of phenomena and processes are expected of students. Features that examination answers share with textbooks are that they are summaries of received knowledge, regarded by writer and (ideally) by reader, as fact, and unlikely to be hedged to any marked extent.

Figure 5.1 is an example of an exam question in first year Chemistry at the University of Natal in Durban:

Figure 5.1: First year chemistry exam question

Describe the production of magnesium from seawater. Give the unbalanced equations and approximate conditions for the reactions that occur.

Figure 5.2 is a student answer to the question, in the form of a procedure (Butt et al 1999:22), and as such, can be compared to similar information from a textbook. Such information is provided in Figure 5.3, which is an extract from a first year textbook (Chang 1998:143) containing the answer to the question. It too takes the form of a procedure. It is interesting to note that both the student answer and textbook are very

Figure 5.2: Student exam answer

[1]Magnesium is found in seawater dissolved as $MgCl_2$. [2]In order to extract the magnesium from the seawater it needs to be in an insoluble form. [3]$Mg(OH)_2$ is fairly insoluble. [4]To form the hydroxide seashells are used.

$CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$
Seashells lime

$CaO\,(s) + H_2O \rightarrow Ca(OH)_2\,(s)$
$MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2\,(s) + CaCl_2$

The insoluble $Mg(OH)_2$ is filtered off. HCl is used to produce $MgCl_2$ again.
$Mg(OH)_2\,(s) + HCl\,(aq) \rightarrow MgCl_2\,(aq) + H_2O$
On evaporation solid $MgCl_2$ is left. This is melted to give magnesium metal and chlorine gas.
$MgCl_2 \rightarrow Mg\,(s) + Cl_2\,(g)$
708° C

factual, with little hedging or evaluation. This is reflected in the fact that the textbook contains no hedging and the only evaluation is in the first two sentences: magnesium is '*valuable*', and the procedure used to recover it is '*cheaper*' than other procedures. This explicit valuation of '*valuable*' metals that can be 'cheaply' recovered is what we might have predicted of industrial chemistry, which aims to produce industrially useful and commercially valuable substances at as low cost as possible. The student's answer's only hedge is in sentence 3 where $Mg(OH)_2$ is said to be '*fairly*' insoluble. This is an attribute hedge (which shows the correspondence of p to reality and involves a qualification of predicate intensity. (Hyland 1996c: 439))

Figure 5.3: Extract from first year Chemistry textbook (Chang 1998)

[1]Magnesium is a valuable light-weight metal used as a structural material as well as in alloys, in batteries and in chemical synthesis. [2]Although magnesium is plentiful in Earth's crust it is cheaper to 'mine' the metal from seawater. In the first stage of the recovery of magnesium, limestone ($CaCO_3$) is heated at high temperatures to produce quicklime, or calcium oxide (CaO):

$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$

When calcium oxide is treated with seawater, it forms calcium hydroxide [$Ca(OH)_2$], which is slightly soluble and ionises to give Ca^{2+} and OH^- ions:

$CaO\ (s) + H_2O\ (l) \rightarrow Ca^{2+}\ (aq) + 2OH^-\ (aq)$

The surplus hydroxide ions cause the much less soluble magnesium hydroxide to precipitate:

$Mg^{2+}\ (aq) + 2OH^-\ (aq) \rightarrow Mg(OH)_2\ (s)$

The solid magnesium hydroxide is filtered and reacted with hydrochloric acid to form magnesium chloride $MgCl_2$

$Mg(OH)_2\ (s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2O\ (l)$

After the water is evaporated, the solid magnesium chloride is melted in a steel cell. The molten magensium chloride contains both Mg^{2+} and Cl^- ions. The half-reactions are

$Mg^{2+} + 2e^- \rightarrow Mg$

$2Cl^- \rightarrow Cl_2 + 2e^-$

The overall reaction is

$MgCl_2\ (l) \rightarrow Mg\ (l) + Cl_2\ (g)$

This is how magnesium metal is produced. The chlorine gas can be converted to hydrochloric acid and recycled through the process.

The textbook answer is longer than the student exam answer, and the first paragraph contains more general information. This is in the form of relational processes:

[1]*Magnesium is a valuable metal* (identifying process)

[2]*Magnesium is plentiful* (attributive process)

[2]*It is cheaper* (attributive process)

However the textbook and student answer are very similar both in genre (both are procedures), and in content. Figure 5.4 lists two questions from a first year Biology exam

(University of Natal, Durban). These provide further evidence that textbooks in general are a model for exam 'essay' answers.

Figure 5.4: First year Biology exam questions.

1. Describe in detail the structure and functions of bacterial flagella and pili.
2. Ongoing intracellular metabolism is absolutely dependant on the action of a broad range of enzymes. Explain why this is so.

It is clear that the answer to question 1 in Figure 5.4 must take the form of an information report, which chapter 4.2 suggests is a common genre in textbooks. Information reports 'present factual information about a class of things usually by first classifying them and then describing their characteristics' (Butt et al 1999:17). The answer to question 2 in Figure 5.4 is likely to be in the form of an explanation which explains 'why things are as they are' (Butt et al 1999:17).

This very brief look at some exam questions in first year Chemistry and Biology indicates that exam questions are designed to elicit answers from students which are modelled on textbooks, and that the genre 'science exam answers' is likely to be closely similar to genres found in textbooks. This suggestion is an area that would benefit from further research, as it has implications for teaching of academic literacy to science students. As indicated above, I turn my attention next to the extent to which research articles show similarities with student lab reports.

As explained in section 2.4.3, Braine (1989) collected 61 assignments in ten science and engineering courses and found that 52 (85%) of the tasks involved a report on a 'specified participatory experience', that is lab reports. I argued in chapter 2 that lab reports are "proto-research articles", as they have some of the same functions as research articles. Like research articles, student lab reports are expected to place the work done in the context of the literature, provide a full enough account of the method used, and convince the reader (lecturer) that the work was carefully and accurately performed. Like research articles, student lab reports are expected to indicate the extent to which the work is continuous with accepted facts in the literature. It is in this point however that student lab reports differ from research articles in that they are not expected to put forward any new knowledge claims. Any deviations from accepted facts are assumed by both the reader and the writer of student lab reports to be the result of error or poor technique in performing the method. As a result students often 'fudge' their results to make them coincide more closely with the 'correct' answer. Research articles, by contrast, must advance new knowledge claims, and must convince the reader that their deviations from

Figure 5.5: Lab report guidelines

Title: Standardisation of Hydrochloric Acid.

Introduction

Write a few lines introducing the purpose of this experiment:-

____
____
____
____
____
____
____
____

Procedure

Write a few lines describing what you did

____
____
____
____
____

Results

(a) Preparation of the standard solution of sodium carbonate

Rough weight of bottle + sodium carbonate	=	g
Rough weight of bottle	=	g
Accurate weight of bottle + sodium carbonate	=	g
Accurate weight of bottle + residual Na_2CO_3	=	g
Mass of sodium carbonate in 250 ml flask	=	g

(b) Molarity of standard solution of sodium carbonate =

(c) Titrations

	1st titration	2nd titration	3rd titration
Initial reading			
Final reading			
Titre			

(d) Standardisation of the HCl

Average titre =

Equation for the reaction is:

No of moles of sodium carbonate being titrated =

No. of moles of HCl in the average titre =

No. of moles of HCl in 1 litre =

Molarity of the HCl =

Conclusion

Write a couple of lines by way of conclusion:

____
____

accepted facts in the literature are actually advances in knowledge and the discovery of something new, rather than errors or the result of poor technique.

The worksheet above in Figure 5.5 provides guidance to first year Chemistry students on how to write a lab report. It was devised and used by a colleague at the beginning of the academic year, which is when students first start doing lab reports. As we can see, it follows the Introduction-Method-Results-Discussion format (cf. section 2.7.2) of a research article closely, but the Discussion section is severely abbreviated into a two-line 'Conclusion'. This is perhaps because at the beginning of the first year Chemistry course, one aim of practical work is to teach students to use equipment and master general lab procedures. Figure 5.6 is an extract from my colleague's instructions to his students on how to do the practical, which he provided on a separate sheet:

Figure 5.6: Extract from instructions on how to do Chemistry lab.

> The aim of this experiment is to develop your manipulative skills with respect to accurate weighing, quantitative transfers of liquids and solids, making dilutions and undertaking titrations. These skills will be developed through an exercise to determine the strength of a solution of hydrochloric acid by its reaction with anhydrous sodium carbonate.

An example of a student Biochemistry lab report is found in pages 52-55 of the appendix. This was written by a second year Biology student at the University of Natal. It was judged by the staff member who marked the report (who assigned it a mark of 9.5/10) to be a good report. This report clearly follows the Introduction-Method-Results-Discussion format. Its discourse features correspond in some degree to those of a research article, but some discourse features reflect the student/lecturer relationship between writer and reader. The writer opens the account with an Introduction demonstrating familiarity with relevant concepts and making reference to relevant literature, as evidenced in the two footnotes. The reference in the first line to "*A Russian Botanist, Tswett ...*" gives the impression of a student demonstrating to the lecturer that relevant texts have been read; in my opinion such a formulation is more typical of a textbook. It is unlikely in a research article as the writer of a research article, while providing information possibly unknown to the section of the audience not active in the field, would be more likely to show politeness to such readers by pretending that readers were aware of Tswett, his country of origin, discipline and research.

The Method section of the report is of course framed in the passive voice: "*The tap was opened...20 test tubes were numbered...More eluting buffer was added. .*" Like the

Introduction, the Discussion has some of the definiteness of the textbook genre. An example is the lack of modality in "*It is for this reason that the protein molecules in the serum do not all pass through the column at the same rate.*" However, in the last three paragraphs of the discussion, the writer *does* hedge statements such as "*This could account for the negative values that were obtained.*" Although all hedges used by this student are content-related rather than reader-related (i.e. they function to indicate writer uncertainty rather than deference to the reader), this tentativeness is nevertheless evidence of one of the ways that this student lab report reflects the discourse norms of research articles.

The above discussion has provided some evidence that textbooks are the models for writing that undergraduate science students are called upon to produce in exam essays and "short exam answers". If exam answers are indeed modelled on textbooks, it is important not to remove or alter the textbook unless the intention is also to remove or alter the exam answers that students are expected to produce. Research articles, by contrast, are the target form of student lab reports. They correspond to research articles in form as well as in some discourse features.

5.3 The use of popular science texts in the teaching of scientific writing

As a teacher of scientific writing, I often provide my students with popular science articles (such as the popular articles in pages 22-35 of the appendix) as sources of information for what they write. One of my motivations in doing this research was to get an insight into the extent to which such a practice is justified either in terms of similarity of genre or register between popular texts and academic texts or in terms of the value of ideological differences between popular and academic forms. Section 5.2 has suggested that the factual genres found in textbooks are used as models for writing expected of science students in exams and some assignments. Research articles are the target form (although not the model) for laboratory reports produced by science students. However, falling as they do into news genres, popular articles are not models for science students. In this section I consider whether popular genres have anything to offer science students in terms of register or ideology. I do so by, in section 5.3.1, briefly comparing academic and popular genres in terms of register and ideology. I then, in 5.3.2, describe the scientific writing course I teach, and in 5.3.3, discuss the use of popular articles in the acquisition of scientific literacy, with specific reference to the course I teach.

5.3.1 Comparison between popular and academic texts

To guide judgement concerning the value of using popular science texts in teaching either science or scientific literacy, this section will briefly compare popular and academic texts at the levels of register and ideology. The purpose of academic and popular texts is different. Research articles function to persuade readers of their knowledge claims (Myers 1989), textbooks to summarise all knowledge that has currently been endorsed as fact by the research community, while popular texts function as narratives of research, reporting on new knowledge claims that have not yet been endorsed as fact by the research community. As a result, academic texts focus on theories (research articles and textbooks) and methods (research articles) while popular articles focus on people and what they say and think.

In line with these different purposes, there are differences in the source of information in these different genres. The source of information in popular articles is the human participants in the article. The popular texts in this study are structured as 'debates' between contesting voices. Because of this 'debate' structure, evaluation of propositions is sequentially positive and negative. Because the source of information is the human participants, the writer is not implicated in any evaluation. By contrast neither research articles nor textbooks are structured as debates. The source of information in research articles is mainly the writer. In order to maximise the chance of the research article being convincing to the reader, evaluation is more likely to be positive than negative. Writers evaluate negatively neither their own ideas nor the ideas of other researchers (which could offend readers who disagree). In textbooks, the source of information is apparently the writer (although in reality the writer is summarising information from unspecified research articles). Textbook writers, perhaps because they represent the powerful research community, are more overt in their evaluation of ideas than are writers of research articles.

As this implies, attitude towards human participants in the texts is in fact a very prominent difference between popular and academic science texts. This difference is associated with different ways of establishing objectivity. Academic texts have far fewer human participants than do popular texts. In this study the average number of human participants per 1000 words is 26 in the popular texts, but only 13 in the textbooks. In the popular texts human participants are far more likely to be specific (i.e. real scientists) rather than generic, which is the norm in textbooks. The popular texts are also far more likely to personalise human participants, for example by providing their first names and affiliated institutions. This difference is one of the features leading to the impression that two of the popular science texts in my study (the Scientific American and Time articles) are narratives of knowledge claims (other features are the presence of many temporal conjunctions referring to present time, and nominalised mental and verbal processes). This difference in the number of human participants can be traced to the different ways that objectivity is established in academic compared to popular texts. Academic texts remove people (and thus the associations of subjectivity and emotion) while authors of popular texts achieve the impression of objectivity by attributing ideas and utterances to the human participants. That this is an appearance of objectivity only is supported in the use of marked themes in the popular texts in my study, showing that the writer is directing the interpretation of the text by the reader (cf. section 4.6.2.1). Because objectivity is not established in popular texts through removal of human participants, passivisation and nominalisation are not employed in popular texts for the purpose of avoiding mention of agency (cf. section 4.6.2.2).

The difference in approach to human participants between academic and popular texts is accompanied by a number of interpersonal differences. In textbooks and research articles solidarity with the reader is shown through formality (technical language, nominalisation, pasivisation and impersonal tone, and in the case of research articles and one of the textbooks in my study, by citation of references (cf. section 4.6.3.1). By contrast the popular texts are more likely to show solidarity with the reader through treating the scientist participants as personalities, by humour, and, if the readers are non-scientists, by distancing the reader and writer from scientists as a group. The textbooks and research article signal objectivity through impersonality, achieved through nominalisation, pasivisation and omission of agent. Popular texts by contrast achieve objectivity through attribution of ideas and utterances to the human participants in the text.

Popular articles show greater variation than do academic texts in who the projected readers are and the extent to which the readers are expected to be scientists or not or even whether they are expected to be positive towards science or not.

Power relations between reader and writer appear to be equal in the popular texts. Writers of popular articles make the reader feel recognised in a number of ways: by including the reader in fields outside their own field, narrative form, enthusiasm for topic, humour and endorsing the projected values of the reader (quantitative science in the case of Scientific American and a shared negative assessment of science in the case of the Mail and Guardian).

By contrast, power relations between reader and writer are unequal in research articles and textbooks. Myers (1989) has characterised the reader of research articles as representing the research community and as thus much more powerful than the writer. Writers of research articles use solidarity politeness (reader-oriented hedges) to mitigate FTAs to readers. By contrast, in textbooks, it is the writer who, in summarising the ideas of the research community and 'speaking for' it, is more powerful than the reader is. Concerns with readers' 'face' (in having to accommodate new information that may contradict readers' previous explanations for phenomena) are therefore not, in my experience, evident in textbooks.

The interpersonal differences between popular and academic genres outlined above indicate that popular genres are not suitable as the major model of scientific writing for science students. However, ideological differences between academic and popular texts make popular texts a very valuable addition in the education of science students. The fact that popular texts report on new findings, means that they afford a view of science at a stage before it participates in the ideologies of science as authoritative and science as difficult, both of which Lemke (1990) indicates make science difficult to learn. Popular science reports on propositions before they are endorsed by the research community as fact, i.e. before they become authoritative. They also give voice to scientists other than those of iconic status (the 'great names' of science, such as Einstein), who are the only scientists found in textbooks. I discuss this reflection of science as an activity accessible to a wider group, rather than merely to the intelligent few in greater detail below.

5.3.2 Teaching scientific writing: Description of a scientific literacy course

In this section I briefly describe the scientific writing course I teach at the University of Natal in Durban and explain why I have used popular science texts as reading material in this course. As part of this account I provide contextual information.

In the last twenty years the proportion of speakers of English as a second language entering historically white South African universities has increased rapidly. At the University of Natal in Durban, the number of African students, most of whom speak English as a second language, increased from 8% in 1986 to 34% in 2000 (University of Natal Pocket Statistics 2000). At the same time the number of courses in English as a second language at South African universities has also increased in answer to the perceived need to improve the proficiency in English of L2 students. The course I teach is one such course, and it is aimed primarily at second language speakers of English who are, in addition, in a 4-year BSc degree programme, having been admitted to the Science Faculty with fewer than the required number of matriculation points (see Parkinson 2000b). Such students, admitted to tertiary study in an attempt to redress apartheid injustices, are 'under-prepared' for degree study to the extent that, having attended under-resourced schools, which often have under-qualified teachers, they enter university knowing less about science and maths than is usually considered necessary. They take a reduced load of first year science courses (such as Chemistry and Mathematics) and get about twice the normal load of tuition in the first year courses they do take to increase their chances of success.

The course I teach, called Scientific Writing, aims to familiarise students with the factual genres needed for science study, and to give them extensive practise in writing these genres. The course is therefore content-based, the content often being drawn from the other first level courses the students are taking or science topics at an equivalent level. Examples of topics, together with the literacies (cf. section 2.2) I aim to teach in them are found in the table below. The genres that are the focus of the course are the two I discussed in the previous section, namely, lab/research report and the essay (with stress on the <u>information report</u> and <u>explanation</u> genres). In addition, the course gives students opportunities to produce posters (these most commonly are in the form of lab/research report) and oral presentations. Both of these are a feature of most disciplines in the Faculty at second, third or honours level.

Table 5.1: Examples of topics in Scientific Writing course (adapted from Parkinson 2000a)

Topic	**Input**	**Literacies**	**Production by students**
Industrial production of a range of substances, e.g. iron, magnesium	• Range of readings from Chemistry 1 textbooks e.g. extract in figure 5.3 above	Read scientific textbooks Note-taking from written sources Integrate information from a number of sources Distinguish important from incidental information Present information orally and graphically as a poster	Poster (information report genre) Oral presentation
Waste water treatment	• Popular and textbook readings • Visit to waste water plant • Slide presentation explaining water treatment • Visit water treatment labs	Translate experience of an industrial process into written form: flow diagram or essay Anticipate visit by reading about process Integrate experience of process, visit to labs, slide presentation etc. with written sources Organise information into coherent form	Flow diagram or essay (procedure genre)
Ozone hole	• Popular & textbook readings • real data – measurements of ozone in Antarctica and Durban • lecture on ozone	Read and take notes from scientific texts Take notes from lecture Integrate information from written sources and lecture Analyse graphical data Plan & and produce lab report genre Use of sources. citing references etc.	Lab report (research article genre)
Physics of the children's playground e.g. a swing or slide	• Textbook, library books, lecture notes, popular sources • Visit to local playground	Draw links between concepts learnt in physics and the observed world Plan own investigation of mechanics of e.g. swing, roundabout Collect data, and represent it in tables and graphically, and analyse data Explain anomalous findings Plan and revise own writing; Produce lab report genre	Lab report on own collected data (research article genre)

As can be seen from Table 5.1, an important element of the course is reading of texts from which students can extract content knowledge. I use texts from textbooks in the course, and in some cases am able to find research articles that are conceptually simple enough for students. However, about half the reading I give to students in the course is from popular science journals such as Scientific American, New Scientist, and *Technology Review*. I have a number of reasons for this. Firstly, the content of popular science texts is simpler than that of academic texts, particularly research articles. Writers of popular texts do not expect readers to be specialists and as a result they use fewer technical terms and provide meanings of the technical terms they do use. An example is the following from the extract in my study from Time magazine, where the writer does not assume the readers know what iridium is:

> *The revolution began with an unassuming element known as iridium, a rare and hard silvery-white metal related to platinum and gold.*

The information in popularisations is also likely to be conceptually simpler and less mathematically based. For example in the following extract from the Time article, the writer glosses over the mathematics of what they are reporting on:

> *Through intricate statistical gymnastics, the two scientists found that ...*

Illustrations in popularisations are less abstract and more likely to supplement explanations in the text than are research articles where illustrations are more likely to represent results, usually in highly abstract graphs, tables, or inscription records. This is illustrated by comparing the illustrations in the Time article (mainly photographs: see appendix page 27) with the graph in the research article in my study (appendix page 5).

5.3.3 Use of popular texts in the teaching of scientific writing

My particular interest in science popularisations stems from my use, as a teacher of science writing, of popularisations. In the light of the research I have reported on up to this point, I am now in a position to consider what the answers are to the following questions. What insights can my findings in chapter 4 offer my own teaching practice and that of other teachers of scientific writing? Do the differences between popular and academic texts (interpersonal differences and differences in genre) make popular texts unsuitable models for academic writing?

As section 5.2 indicates, on the evidence of student exam answers, student lab reports, and guidance about writing lab reports given to students, the target forms for students are the textbook and the research article. This study has shown that popular articles have significant differences from these academic genres at the interpersonal level, and that they make scientists (the people who make findings) the focus rather than the findings they make, which are the focus of textbooks and research articles. Popular articles should therefore not form all or even most of the reading upon which a scientific writing course is based. Besides differences in genre, if students model their writing too closely on popular texts there is a danger that they might:

- Focus too heavily on human participants
- Cite references in a popular rather than academic style
- Use the passive voice less frequently than it is used in academic texts
- Be somewhat more informal than is acceptable in academic writing

In my teaching I have found that students who are given popular articles as source materials **do** model their academic writing on the popular texts in certain ways. The second of the above features - citing references in a popular rather than academic style - is most prominent. Examples of a popular style of attribution imported by first year students into their academic writing are:

1. ***Paul R Epstein*** *found that drought increases stagnant pools and dams.*
2. *This was supported by an experiment by* ***John B Calhoun*** *in 1962.*
3. ***Paul Reiter who is the chief entomologist at the US government's lab in Puerto Rico*** *argues that climate has no effect on the spread of Malaria.*

In these three examples the writers supply the first name, initial, and, in the case of example 3, the institutional affiliation of the human participants. That is, the writers have selected the popular rather than the academic way of citing their references. This practice has certainly been imported from popular source articles. This, however, is in spite of the academic way of citing references having been stressed in the course, and the students having specifically been instructed to avoid the popular method of attributing ideas.

Examples 1-3 above may also be an indication that use of popular articles may encourage student writers to people their texts with too many human participants. However, in student writing I believe that attributing too much of what is said to source texts is more likely to be acceptable to lecturers than attributing too little. Also, although exam essay writing is likely to be modelled on textbooks, in essays written as assignments, where students are expected to find and read source material, it is likely that students are expected to attribute much of what they say to source texts. Thus, in my opinion, large numbers of attributions, perhaps resulting from the reading of popular texts, are unlikely to be penalised by lecturers.

Popular texts as sources of information may also encourage informal language. An example from a student essay is:

For starters there is no such thing as a perfect drug.

This example represents a level of informality likely to be considered inappropriate in academic writing. This informality may have been encouraged by using popular articles as a source of information. Equally, however, it could have been imported from the writer's own informal/conversational style. As the writer is a second language speaker of English, s/he may view the phrase *'for starters'* as an equivalent of 'for a start', without being aware of the difference in level of formality.

In these aspects, and particularly in the encouragement of a popular rather than academic style of attributing references, popular texts can be said to represent poor models for students. However, besides usually being easier in terms of content (as reflected in chapter 4), and thus making for a suitable first reading/introduction to a topic, I believe that popular texts may be valuable in other ways. I outline these in what follows.

Firstly, Lemke (1990:133) criticises classroom science as overly impersonal. The large number of human participants in popular texts may thus play a useful role for students in making for more personal and 'people-oriented' science.

A second point made by Lemke (1990:137) is his suggestion that classroom teaching represents science as "established, permanent, incontrovertible fact". Popular texts are a valuable addition to the teaching of scientific writing because they give readers an idea of 'science in the making' – what the concerns and issues were before this information was established as fact. Popular articles deal with information that is contested, while textbooks present information that is no longer contested. They are therefore able to present it as if it is factual and permanent. Research articles, too, present information as far as possible as if it were uncontested. They stress continuity with previous findings and remove people from the account. Popular texts, because they report on findings that the research community has not yet endorsed as fact, are distinct from research articles and textbooks in representing findings as provisional and even controversial, and thus provide an insight into science as a social activity that is absent from the other genres. The Time article and even more particularly the Scientific American article in my study indicate that research and scientific evidence do not automatically result in propositions being accepted as fact. They also report on what kind of challenges may be made to scientific evidence. Being exposed to some popular texts is thus likely to combat the ideology pointed to by Lemke (1990) of science as authoritative – something that cannot be challenged and must be believed because it has the stamp of science on it. The Mail and Guardian article in this study represents scientists as not automatically objective, and as motivated by the human and subjective wish to further their own careers. Popular articles are also more likely than are textbooks and research articles to bring ethical concerns to readers' notice. Current examples of concern in journals such as Scientific American, New Scientist and Technology Review are genetically modified plants, cloning, the growth of technologies allowing widespread surveillance by authorities etc.

Figure 5.7: Assignment asking students to write a newspaper article on a conference.

Oral presentations this semester are in the form of a 'mini-conference' on Energy and Pollution. Everyone in the class will attend the mini-conference to present their own 10-minute talk and to listen to the presentations of others. Part of the mark for this assignment is based on the following newspaper report on the mini-conference:

Write a 300-400 word newspaper report on the conference. Two examples of news reports on scientific conferences are provided. As these articles do, you should report on some highlights or a particular theme of the conference, possibly discussing two or three of the most interesting presentations, or the presentations with the most relevance to us in South Africa. Alternatively your report can draw some overall conclusions on the topic of the conference; support what you say by referring to individual presentations. You may quote speakers if you wish. You should write the article as if it were going to be published in *Dome**, so write it with the readers of *Dome* in mind.

*the campus newspaper.

A third use for popular science texts is that if students can learn to distinguish some of the characteristics of popular and academic science, this will give them a deeper understanding of the register of academic genres (e.g. textbook). Lemke (1990) recommends that science teachers should encourage students to translate back and forth between formal science and explanations in colloquial language. Similarly, popular science may well be of use to those learning the discourse of science for the reason that if it is necessary to 'translate' from popular to academic registers, this makes students distinguish the two. However, it needs to be made explicit to students that there is a register difference, and what the features of popular and academic science are. By this means, students' knowledge of the academic register becomes deeper. I suggest that it is also useful to students sometimes to be called upon to reformulate academic registers for a popular audience. This gives students skills in communicating with non-scientists. An example of an assignment I give my students that requires them to do this is found in Figure 5.7.

Students are asked to research a particular topic (for example 'Energy from Wind') and present a 10-minute talk on this. They are encouraged to choose a particular focus of the 'conference' referred to in the assignment to report on in their newspaper article: for example, renewable sources of energy. There is usually some discussion, in groups and as a class, about the features of the exemplary articles. These include organisation of information in news articles, the titles, how human participants in the articles are cited, what the author's attitude is to what s/he is reporting on and how this is communicated etc.

To sum up, in this section I have suggested that although popular texts differ significantly from academic texts at the level of register, they do nevertheless make a valuable addition to a scientific writing course for three reasons. Firstly, popular texts are conceptually simpler than academic texts and thus make an appropriate first reading on a topic. Secondly popular texts give students insight into the scientific process. This insight includes the way that popular articles represent scientific findings as open to challenge (contesting the ideology of science as authoritative), and as an ordinary activity available to a group far wider than the 'great men' of science such as Newton (contesting the ideology of science as too difficult for ordinary people). Finally, being called upon to 'translate' from popular to academic genres, and even, occasionally, to frame their scientific ideas for a non-scientific audience is valuable to students in that it encourages a deeper knowledge of academic scientific register.

5.4 Popular science texts: insights for teaching science and for science textbooks

Chapter 2 of this thesis recounts Lemke's (1990) suggestions of ways of 'humanising' science classroom discourse to make science easier to learn. In the light of this, what insights can my study of popularisations and science texts for children offer for the teaching of science? In what follows I restrict my remarks to the teaching of science at secondary and tertiary level.

As mentioned in section 5.3 above, Lemke (1990:137) outlines two sets of beliefs that he suggests make science difficult to learn. These are that science is authoritative, and that science is difficult. Firstly, science is represented as authoritative in that facts are characterised as divorced from dependence on theory, from people and from the origin of facts in social activity. It is easy to see how this is related to how a proposition is established as a fact in research science. Secondly, Lemke (1990:138) suggests that science is represented as difficult and only available to the highly intelligent. He maintains that, far from being in opposition to common sense, as it is commonly represented, science is actually continuous with common sense. He suggests (1990:139) that what makes science difficult in reality is that the ways in which it is presented, (for example impersonally), are unfamiliar to most people. He maintains (1990:133) that school science follows the rules indicated in Table 5.2, which follows. The table shows which popular texts in this study violate these rules. If we accept Lemke's suggestion that these rules do indeed make science hard to learn, then access to popular texts may be of use to students at both secondary and tertiary level.

Table 5.2 Rules of scientific language (Lemke 1990:133)

Rules of scientific language	**Texts in this thesis that violate this rule**
1. Be as verbally explicit and universal as possible	
2. Avoid colloquial forms of language	Mail and Guardian article
3. Use technical terms in place of colloquial synonyms	
4. Avoid personification and use of human attributes	
5. Avoid metaphoric and figurative language	Mail and Guardian article
6. Be serious and dignified. Avoid sensationalism	Mail and Guardian article
7. Avoid personalities	Time and Scientific American articles
8. Avoid reference to fiction or fantasy	Cartoon about the film Meteor*
9. (Use causal forms and) avoid narrative and dramatic accounts	Time and Scientific American articles, Tyrannosaurus rex

* This cartoon appeared in New Scientist and is reproduced on page 56 of the appendix.

Lemke (1990:143) draws attention to the ahistorical representation of science in that theories that have been superseded are ignored. Yet it is difficult to suggest how to counteract this as a problem. We would hardly want to include large numbers of theories to which the research community does not subscribe. Because popular science articles report on findings that are not yet endorsed by the research community, they present the findings as provisional, as not yet 'fact'. If teachers encourage their students to read popular science texts this would be one way of communicating to students the social nature of science, and for students to get an insight into 'science in the making'. It would give students an insight into how facts are established through negotiation and consensus, rather than merely being uncovered by scientists in their pre-existing state. They would also get an insight into the evidential basis upon which science is built. This would challenge the ideology of science as authoritative.

Lemke (1990) suggests that learning science is made more difficult through the ideology of objectivity reflected in removal of people from scientific accounts. I have argued in chapter 4 that within the context of research articles, the discourse features (e.g. removal of people, nominalisation, passivisation) that reflect the ideology of objectivity are necessary for any writer who wants to have his/her knowledge claims accepted. This makes them entirely functional within the social context of research science. This ideology of objectivity reflects not only the belief system of science but also the context of the western cultural valuation of emotion as the polar opposite of reason. We prove that something is true, valid, credible, and thus a fact, partly by representing it as based on reason, not on emotion. To do this we remove people from the account to make the account universal.

Within the tertiary textbooks in this study (and indeed in all conventional textbooks) removal of people serves a slightly different function. Here the facts are all-important. Who thought of them first is unimportant. Lemke (1990) and others have argued that this removal of people from school science is part of what makes it hard to learn. On the face of it introducing more people into textbooks would appear to be a solution to this. Popular science provides one possible way to do this. However I personally do not see this as a solution for a number of reasons. Firstly, so many people are involved in proposing scientific facts that this could result in the introduction of a boring and difficult catalogue of names into textbooks. I do not see transforming science into history as necessarily making science easier to learn. Secondly, attempts to select the most prominent researchers to represent the people behind science risk the introduction of 'great men in science' which in my opinion can also be alienating to students, and feed into the ideology of science as the preserve of the highly intelligent. It leaves the readers outside of science, and construes scientists as 'other'. An alternative means of personalising science in school textbooks (and thereby engaging the reader's interest) would be to include more practical work in textbooks. If the reader actually conducts an investigation her/himself, s/he becomes identified with science, and, I believe, this is far more likely to make science more accessible than including a history of science in textbooks.

A third reason why I would not advise 'humanising' textbooks by introducing more people into them in a way similar to popular science texts is the different role played by human participants in popular texts compared to textbooks. My analysis in chapter 4 indicates that the introduction of large numbers of human participants into popular science texts functions partly in the establishing of objectivity in a journalistic context, and partly because who has proposed a new explanation/finding is what is news. To import this practice into textbooks would not be functional.

A further reason against introducing popular forms into textbooks is that news genres (such as those I have discussed in this thesis – the issues report and the opinion piece) are less suitable for expressing scientific ideas and explanations than are the factual genres commonly found in textbooks. However, it is likely that popular science texts that are not news genres – for example long articles written by the researchers themselves – could provide more useful models for engaging readers than the popular news genres in this study. This long popular article is a genre that needs further study.

Finally, another argument against introducing popular science features into textbooks is that textbook genres are a target form of the later years of high school just as textbook genres and the research article are target forms of tertiary study. Replacing textbooks genres with news genres would thus not be to the advantage of readers.

Although I regard the introduction of large numbers of human participants into textbooks as infeasible for the above reasons, I suggest that current popular science texts could usefully be provided as reading for secondary and tertiary students. Such texts could be drawn from existing sources such as newspapers, news magazines and popular science journals, or could be introduced into existing magazines for adolescents. Alternatively popular science magazines could be established for adolescents. Popular texts are peopled with large numbers of scientists, very few of whom are 'great men', with the iconic status of Einstein or Darwin, who will eventually be canonised in textbooks. If popular texts were made more available to students, this would challenge the ideology of science as so difficult that it is only available to the highly intelligent few.

Lemke (1990:172) characterises the language of science as a register of English foreign to most students. To enable students to learn this register he makes a number of recommendations. My discussion below indicates the extent to which the inclusion of popular science texts in science teaching would be of value in achieving these recommendations

1. *Science teachers should encourage their students to translate back and forth between colloquial and scientific language.*
   I would regard this ability as essential to learning any specialised register, because unless students can explain a scientific concept in their own everyday language, it is doubtful that they really understand it. As I indicate in section 5.3 above, popular science texts may be of value for the reason that they are somewhat more colloquial, and provide a different view of science from that provided by academic texts.

2. *Science teachers should use non-scientific forms such as narrative and drama.*
   Once again this assumes that certain forms, such as narrative and drama, are easier for children than factual forms. Martin (1989), by contrast, suggests that factual forms are not more difficult, merely less familiar than narrative. There is no evidence whether factual forms are more difficult and if so whether this is because they are inherently more difficult or merely less familiar. This is an area that needs further research. If factual forms are harder (whether inherently so, or from lack of familiarity), I would be inclined to provide more practice in them rather than replace them with other forms for the following reason. In calling scientific discourse a 'foreign register' Lemke (1990:172) makes the analogy with learning a foreign language. In this analogy non-scientific forms such as narrative and drama are the student's 'own language' while scientific forms are the 'foreign language' Learning the 'foreign' scientific forms must of necessity involve practising these forms. A teacher of for example, French, who spoke to his/her English-speaking pupils only in the pupils' English would not be expected to make much headway. I personally see no harm in including forms such as narrative and drama in science teaching so long as they augment rather than replace the factual forms that are, as Martin (1993:167) notes, the target forms in the later years of secondary school. He decries what he reports as a trend in Australian school policy towards privileging non-scientific written forms, (such as stories, plays, poems and cartoons), in the teaching of science. He notes (1993:168) that the removal of traditional textbooks from Australian

classrooms in the last 20 years has resulted in school children being exposed to very few models of scientific writing.

Lemke (1990:172ff) makes the following three further suggestions, to which I respond below:

3. *Science teachers should make reference to actual scientific activities, disputes and persons and provide personal anecdotes and historical examples about scientists.*
4. *Science teachers should describe science as a fallible human social activity (Lemke 1990:175).*
5. *Science teachers should devote class time to discussion of policy questions (Lemke 1990:180).*

These three suggestions are all intended to make science more accessible to learners by representing it as a human activity and not as an unalterable body of pre-existing fact. The suggestions are supported by research into the beliefs about science of school children by Duveen et al (1993), Ryan and Aikenhead (1992) and Driver et al (1994), mentioned in chapter 2. This research indicates that most children view science as a series of discoveries of pre-existing facts that scientists have merely 'discovered'. That is, as discussed in chapter 2, there is little recognition of facts as socially constructed.

Because popular science texts do not view science as a set of hard facts endorsed by the research community, they could play a very useful role in making science easier to learn. Popular texts refer to contemporary scientific activities, disputes and people, and have the advantage of being current news. Because popular science reports on current controversies in science (e.g. the Scientific American and Time articles in my study), it becomes clear that scientists are fallible, and, more importantly, students get an insight into how a proposition becomes a fact. In terms of 5 above, popular science is often concerned with the ethics of science, and with discussion of policies (e.g. government policies on pollution, wildlife, cloning, genetically modified food etc.)

In summary, in this section I have suggested that importing aspects of popular science – such as greater numbers of human participants - into textbooks would be a disadvantage to readers. My reasons for claiming this are firstly that this would alter the textbook, which is a model for writing expected of secondary and tertiary students. Secondly, it would introduce 'great men' into science, and 'historify' science without making it more engaging or easier to learn. Finally, because they focus on people rather than theories and explanations, popular genres are less useful than factual textbook genres for expressing scientific ideas. Instead I suggest that using current popular texts *as well as* textbooks would contest the ideologies of science as authoritative because popular texts deal with ideas not yet accepted by the discourse community which can therefore not be represented as "established, permanent, incontrovertible fact" (Lemke 1990:137). Because popular texts are peopled with large numbers of human participants who are not afforded iconic status, providing popular texts for secondary and tertiary students would also contest the ideology of science as difficult.

5.5 Science texts for children as a preparation for reading textbooks.

The textbooks analysed in this study are university-level ones. They are thus intended for a readership very different in age, background knowledge and reading purpose than the books for children. Nevertheless, there are many similarities between the textbooks and books for children (cf. Chapter 4.2 and 4.5). In what follows I compare (in section 5.5.1) these two genres in terms of register, genre and ideology. I then, in 5.5.2, indicate the pedagogical relevance of these similarities to science teaching

5.5.1 Similarities between science books for children and textbooks

A first similarity between science books for children and textbooks relates to genre. Like textbooks, the books for children present themselves as reference works. They contain a glossary and an index. Usually they start with a contents page with the 'chapter' headings beneath a picture illustrating each 'chapter'. The appendix includes examples of a contents page (appendix page 38), glossary (appendix page 43), and index (appendix page 42) from the books for children in my study.

Features such as the illustrated contents page make the book potentially readable by beginning readers. Although the four books for children in my study present themselves as reference books for children from the very young to children of about 10 years old, they are not dry or boring. Rather they are colourfully illustrated. Illustrations are primary. This is particularly the case in DK Picturepedia (see page 40 of the appendix) where the blocks of text accompany the pictures rather than the other way around. As a result, even a child who cannot read at all is able to enjoy the books. It is interesting to note that, for example in the contents pages and in some cases in the text or 'chapter' itself, pictures are a structuring device in these texts for children. The reader chooses what part to read and in what order based partly on the illustrations.

DK Picturepedia in particular is characterised by the editors as a kind of early encyclopaedia and the first page of the book contains a 'Note to Parents' reproduced on page 44 of the appendix of this thesis. In it the text explicitly points out (to the readers' parents, and by extension those adults who buy the book for libraries) the reference nature of the text. As discussed in section 4.5.5 this book is part of a series designed to initiate children into accessing factual information. The editors envisage the readers as belonging to families who are likely to read the book with the child, and to enjoy and value activities like posing questions and answering these by consulting factual reference works. The assumption appears to be that they are leisured people, and the adult members of the family are already familiar with the 'look it up' approach to reading books. In short, the projected readers of the book are middle class children.

Another way that books for children are generically similar to textbooks is in the genres used (here I use 'genre' in the sense in which it is used in Australian genre studies). Textbooks are structured as a range of different factual genres, especially information report, explanation, procedure and discussion. In terms of genre, the texts for children are surprisingly similar to the textbooks in spite of the age difference of the projected readers. The texts for children in this study all fall into the genre of information report, although one of the texts for children rehearses the information first in a narrative section. This suggests that this text views narrative as likely to make the factual content of the text more accessible to the child reader.

At the level of register the similarities are also marked. Below I illustrate similarities in terms of human participants, organisation of the message, and similarities in terms of hedging and evaluation. The science texts for children in my data are, like textbooks, not peopled by 'personalities', that is human participants that we get to know, or who are allowed to 'speak for themselves'. Instead, like textbooks, the human participants are generic 'scientists' and 'we'. Examples are:

> ***Some scientists** think that a giant meteorite ten kilometres wide fell from space and hit our planet* (from All about Dinosaurs)

> *With regard to the dinosaurs and the K/T boundary* ***many palaeontologists*** *would maintain that these reptiles had been gradually dying out for some time during the Cretaceous* (from Duff, the first year textbook).

This reference to generic scientists is in contrast to the popular articles for adults, where there are plenty of specific human participants. These are treated as personalities: their first names and affiliated research institutions are mentioned:

> *In 1979* ***Luis W. Alvarez, Walter Alvarez, Frank Asaro and Helen V Michel of the University of California at Berkeley*** *reported that a layer of clay deposited at the end of the Cretaceous period (about 65 million years ago) contains anomalously high levels of iridium.* (from the Scientific American article)

The Time magazine article in my study (for a wider, less scientific audience than the Scientific American article) goes even further in humanising scientists:

> *Alvarez,* ***his curiosity aroused****, shipped samples of the sediment back to* ***his father Luis, a Nobel-prizewinning physicist at the University of California****, who had the clay analysed.*

The Time magazine article even speaks of scientists in semi-religious/mystical terms:

> *And the following day, at the nearby University of California campus in Berkeley, Physicist Richard Muller,* ***like a seer divining entrails****, scrutinises the new batch of video recordings from Lafayette... These* ***quests*** *are all part of the...*

Thus science books for children, like textbooks, incline towards the 'objective' portrayal of scientists, unlike the popularisations, which show the scientists as people with families, and even as personalities with religious or mystical authority.

In chapter 4 I characterise the books for children as textbooks for young children with people (*we* and *scientists*) brought into the picture, as in the popular texts, to encourage reader involvement. Like the textbooks, the books for children are not about scientists, but rather about the facts of what happened. However two of the four texts for children analysed in my study do include the reader in the text (namely All about Dinosaurs and DK Picturepedia). This is one of the ways that books for children are more engaging of the reader than textbooks. The number of human participants per 1000 words is similar in the two genres. In the texts in my study both genres have an average of 13 human participants per 1000 words. It appears that, as in the textbooks, books for children remove human participants because the facts and ideas are more important than the people who first proposed them are.

As expected the books for children are the most literal and least abstract texts in the study. In line with this there are fewer relational processes, particularly identifying process (which congruently express abstract ideas) in the books for children. On average 55% of processes in books for children are material processes, compared with only 30% in the textbooks in my study.

Focus in the books for children is on what happened to the dinosaurs during the Cretaceous extinction (of particular importance in Tyrannosaurus rex) and the theories that 'we' and scientists have about how it happened. What happened to the dinosaurs during the Cretaceaous extinction is a minor focus in the simplest of the three textbooks, Trefil and Hazen, the textbook for non-science students. In line with this literal focus, circumstances of time and place in the books for children refer to the time and place of the dinosaurs rather than modern time and place as in the popular texts in my study. For example the following circumstance is typical of circumstances in the books for children:

> *When dinosaurs became extinct* ***at the end of the Cretaceous period, 65 million years ago*** (from Prehistoric Life).

By contrast the following focus on recent time is typical of the popular texts.

> *The impetus to extend the isolated event proposed by the Berkeley workers into a cycle of catastrophes came* ***in late 1983*** (from the Scientific American article).

In terms of organising the message there are some similarities between the books for children and textbooks. The two textbooks aimed at science students are very highly nominalised (50 nominalisations per 1000 words on average). The number of nominalisations in the third textbook in the study, the one aimed at non-science students, is much lower (7 per 1000 words), and is comparable to the number of nominalisations in the texts for children (5 per 1000 words on average).

Another similarity in organisation is that central propositions are packaged into facts in all three of the textbooks and in two of the four books for children in my study. These propositions are often subjected to evaluative commentary sited in the ranking clause (in bold below). Examples are:

We are not sure *[[why this happened]].* (from All about Dinosaurs)
But no single theory can explain *[[what really happened]].* (from DK Picturepedia)

Another idea is [[that the weather got colder and the dinosaurs could not survive through the icy winters]]. (from All about Dinosaurs).
But ***there is also evidence*** *[[that a great meteorite, measuring some 9.5 kilometres across, struck the Earth at the time of the Cretaceous extinctions]].* (Prehistoric Life)
So it is maintained *that [[the Earth was hit by an extra-terrestrial body]].* (Duff, the first year textbook)
Perhaps the most interesting and controversial proposal *made in palaeobiology in the last decade is the proposal [[that the Late Cretaceous mass extinction was triggered by the impact of a large asteroid]].* (McGhee, the textbook for graduate students).
The fossil record ***shows,*** *however, that [[not all extinctions are "normal."]].* (Trefil and Hazen, the textbook for non-science students).
Thus ***it appears that*** *[[the Earth was enveloped in a dust cloud, anomalously enriched in iridium, at the end of the Cretaceous]].* (McGhee, the textbook for graduate students).
Lastly, it should be noted that [[the climatic predictions of the impact hypothesis are strongly model-dependant]]. (McGhee, the textbook for graduate students)

The function of passivisation in the books for children is also similar to its function in the textbooks in the study. Once again, although there is extensive use of the passive in the two textbooks intended for science students, the amount of passivisation in the textbook intended for non-science students (5.4 instances of the passive voice per 1000 words) is comparable with the amount in the books for children (5.9 instances of the passive voice per 1000 words). Textbooks and children's books most often use the passive to foreground the goal as more central than the agent to meaning. The agent may be present or may be implied as the generic 'scientists'.

A look at the illustrations of the different types of text is also very revealing. Here again we find that there is a move towards objectivity in books for children and textbooks. In the context of illustrations, objective implies illustrations that offer information to the viewer in an apparently dispassionate way. By comparison, a picture of a person, who looks at us and demands a social response from us would be a subjective picture (Kress and van Leuwen 1996). An example from a highly objective text is the picture of the Martian moon in McGhee (see appendix page 13). The top-down angle is the angle of maximum power of the viewer, and is oriented towards 'theoretical' 'god-like point of view' objective knowledge. In being a photograph this image has a high level of truth-value.

This can be compared with the bottom central picture from DK Picturepedia (page 40 in the appendix). Although it is obviously not a photograph, it looks like one, giving it high truth-value. We, the viewers, are once again given the "god-like observer view" from outside earth.

Another objective picture, classifying animals that became extinct or survived the extinction is found in the top right of Prehistoric Life (see page 46 in the appendix). The animals are presented from side, and they are all the same size. This is a classificatory picture, an offer of objective information to the viewer.

The number and highly coloured nature of illustrations in books for children is one difference from textbooks, and represents one of the ways that books for children attempt to make the content more accessible to readers, some of whom may be unable to read text. Other concessions made by the texts for children to the fact that their readers are children are simple nominal groups (cf. section 4.5.2.2), few identifying processes (cf. section 4.5.1.2) and in one of the texts, an initial narrative section (see appendix page 49).

In terms of solidarity of the writer with the reader, the books for children are very like the textbooks, but without the formality of nominalisation, passivisation and a lot of technical terms. Like the textbooks they are serious in tone and mostly factual information report in genre. Importantly, like the textbooks, they identify the reader with scientists as a group.

Like the textbooks the books for children signal objectivity through being relatively impersonal and having little attitudinal lexis. The textbooks and the children's books are once again similar in their attitudes to science and scientists. Science in these texts is based on quantitative methods and is an unmarked activity. Being a scientist is an unmarked occupation and there is no suggestion that they are other than sincere and well-intentioned. As in the textbooks there is not distancing of reader and writer from scientists as a group. Power relations between reader and writer in books for children is the same as in textbooks in that the writer is an expert supplying information while the reader is a relative novice.

Textbooks are similar to books for children in that reliability hedges (which indicate the writer's confidence in the truth of a proposition) are very common in these genres. I explain this in terms of the writers of these genres wishing to communicate to the readers the best approximation to the truth available to them at the moment, including an accurate measure of their uncertainty on the matter.

Evaluation in the textbooks and books for children appears to be more overt than that in the popular texts and the research article. In the textbooks and books for children the source of information is usually the writer or apparently the writer, the source actually being unspecified research articles. Thus the evaluation appears to come from the writer.

In summary, there are a number of features that indicate that science books for children are more similar to textbooks than they are to other types of science writing. Firstly there is the fact that science books for children view themselves as reference books in that they have contents pages, glossaries and indexes. One of the books in my study (namely, DK Picturepedia) also viewed itself as an early encyclopaedia.

Secondly, like textbooks, science books for children present themselves as objective in a number of important ways. The human participants are generic "*scientists*" or "*geologists*", not the real named people and personalities. This contrasts with popular articles for adults where the human side of the scientists is stressed. They are named, come from research institutions, even have fathers, and in some cases are treated as having religious authority. The introduction of people into the account reduces the apparent objectivity of the text. Textbooks and books for children, although they by no means pretend to know everything, are more certain and more cut and dried in the way they present information. They present information as what is accepted as fact at the moment about this particular issue. Finally, the pictures in science books for children also present themselves as fairly objective depictions compared to the pictures in the popular articles I have looked at.

5.5.2 Pedagogical implications

An important implication of this study can be drawn from the inference that science books for children are directed primarily at middle class children. That the publishers see middle class parents as the buyers of science books for children has been argued above (section 5.5.1) in connection with one of the four books for children. It is here that primary schools have a role to play in making this sort of book accessible to young children who are not from the kinds of families that are the target of the note in Figure 4.5.1. Primary school teachers are able to borrow relatively large numbers of library books from public library, and teachers often use this facility to provide personal reading for their pupils on factual topics studied in science, geography, history etc. (personal communication, Mrs Clow, grade 5 teacher, Manor Gardens Primary school, Durban). However, in the South African situation, for well-known historical reasons, well-stocked libraries are more likely to be situated in middle-class, mainly 'white' areas than in working-class, mainly 'black' areas. With the change in government in 1994, it can only be hoped that this will gradually be changed.

Another important implication of my research is that in spite of the fact that science books for children are factual genres and in spite of the fact that, like research articles and textbooks, they also remove people from science, children like them. This may imply that factual genres are not inherently more difficult to understand, and that science doesn't need to be personalised in order for children to learn it. Lemke (1990) and others have suggested that to make science more accessible we need to include other genres such as narrative, drama or poetry. The assumption is that these are easier than factual genres. However this has not been proved. Instead, perhaps science books for children need to be more widely available. Schools could play a much greater role in encouraging the reading of factual texts not only as sources of information but also as reading books. In my experience the reading books that children are given to learn to read are almost exclusively narratives. Future study is needed into whether children actually do find factual texts more difficult than narrative. If they do find factual texts more difficult, is the answer to remove factual texts? Should we instead provide more of them to school children so that they can gain greater familiarity with them, making science and other factual subjects such as History more accessible in the later years of school?

5.6 Summary

In this chapter I have argued that the textbook is a model for writing that science students produce in exams, and that the research article is the target form for student laboratory reports. Similarly, as Martin (1993:167) points out, textbooks are the main models of written science for school children. As a result I have argued that popular writing should not be imported into textbooks in the belief that this will humanise science and make it easier to learn. This study indicates that popular science is too different in genre and focus from textbooks to serve as a model for student writing.

Instead of importing popular writing, or aspects of it, into textbooks, I suggest that both science teaching and teaching of scientific literacy would benefit from the use of popular texts. The main benefit would be to expose students to a different ideological focus from that found in textbooks and research articles. In textbooks the focus is on information accepted as fact by the research community, and in research articles propositions are treated as accepted fact as far as possible in order to achieve greatest credibility with readers. To achieve their aims, both genres remove reference to the personal, making science appear impersonal and thus objective. By contrast with these two genres, popular science treats scientific findings as provisional, and gives a more personal view into the construction of scientific facts through consensus and negotiation. I suggest (a) humanising school science by using practical work to bring the reader (rather than 'great men') into the text. (b) I suggest introducing both school children and tertiary students to a greater amount of popular science. This would give a greater impression of science as an historical and social activity and alter the widespread idea of science as merely uncovering pre-existing facts. It would thereby combat the ideology of science as authoritative.

Further than this, I support Martin's (1993:167) contention that it is not to the benefit of primary school children to change textbooks so that they use non-factual genres, and thus give the reader little experience of reading the kind of writing that they will be expected to produce in secondary school. I support Martin's (1989) claim that factual writing is not intrinsically harder than narrative, but often less familiar. This is an area that calls for more research. However Martin's (1989) claim is supported by the large degree of similarity in terms of register and genre between science books for children and textbooks, even textbooks at an advanced level. I have suggested in this chapter that science books for children are a valuable preparation for reading textbooks in later life, and that South African primary schools could play a useful role in making these books more available to pupils who may not have had access to them at home.

CHAPTER 6: CONCLUSION

6.0 Introduction

In this chapter I provide a brief summary of the main findings of my research (section 6.1). I also consider the limitations of the study and suggest possibilities for future research (section 6.2).

6.1 Summary of the main findings of my research

As indicated in chapter 1 of this thesis, my research addresses three main questions. These are:

1. *What distinguishes popular scientific genres from academic ones, and how do they relate to each other?*

2. *How does register in representative texts from each genre illuminate the ideological assumptions of each genre?*

3. *What is the pedagogical relevance of an understanding of questions 1 and 2 to science teaching?*

I summarise my answers to each of these three questions in sections 6.1.1, 6.1.2, and 6.1.3 respectively.

6.1.1 Popular scientific genres compared to academic genres.

My first research question considers what features distinguish popular scientific genres from academic ones. Chapter 4 (section 4.6) reports a number of important differences between popular and academic genres at the level of register. It also notes great similarity in terms of both register and genre between textbooks and science books for children (sections 4.5 and 4.6).

I compare popular and academic science genres in sections 4.3, 4.4, 4.6 and 5.3.1 of this thesis. In summary, popular articles differ from academic genres in being peopled with large numbers of human participants. Unlike research articles and textbooks that bury human participants by use of passives and nominalisation, thereby creating the impression of objectivity, popular science articles foreground scientists, and make the account into a narrative of research. Because the scientists are the authorities/experts on which the writer draws, stressing their involvement actually confers objectivity on the writer rather than the converse. To emphasise writer objectivity, in the three popular texts in this study, the writers use sequential positive and negative evaluation to structure the text as a debate/dialogue between scientific experts who give opposing explanations. Marked themes are one of the devices used to signal to the reader that one side of the debate is more valid than the other, indicating the extent to which the objectivity of the writer is appearance rather than reality. Further study is needed before it can be concluded whether this dialogic structuring through sequential positive and negative evaluation is a common structure in popular science texts.

Another difference between popular science and academic texts is that academic texts avoid attitudinal lexis in order to increase the impression of objectivity. Popular texts on the other hand are more likely to use attitudinal lexis.

Contrary to the findings reported by Fahnestock (1986), popular articles in this study are relatively tentative and contain a lot of hedging. However this hedging is different in kind from that in research articles. In my limited survey, popular science articles have as much reliability hedging (which indicates the writer's confidence in the truth of a proposition) as research articles do. They have more writer-oriented hedging (which ascribes an idea and responsibility for the idea to a source). The biggest difference is that popular articles have few reader-oriented hedges (hedge assertiveness and show deference to readers), the most numerous kind of hedge in research articles.

In summary, this comparison of popular and academic genres indicates that the most important difference between popular and academic science genres centres on the fact that in popular texts objectivity is not achieved though removal of human participants. Instead it is achieved through peopling the text with human participants who, being experts, bear responsibility for what is said, rather than the writer bearing that responsibility. Other features of popular articles also support this analysis. These include the preponderance of hedging that attributes what is said to experts, the structuring of the text as a debate between experts, and the role played by the writer in judging the validity of the sides of the debate through attitudinal lexis.

The last of the four genres in my study, science books for children, is another genre that could be regarded as popular, as it is widely read by children, and, like popular science articles, is read for enjoyment rather than for instrumental reasons. There is close similarity between textbooks and children's books. Like textbooks, books for children present themselves as reference works, having a glossary, index, and contents page. Science books for children also employ the same genres (e.g. information report) as textbooks do. Like textbooks, books for children package central propositions into embedded fact clauses. Like textbooks, books for children incline towards an 'objective' impersonal portrayal of scientists, being peopled with generic scientists only, as facts are more important than the people who first proposed them are. Like textbooks, books for children use the passive to foreground the goal as more central to meaning than the agent, which may be present or may be implied as generic 'scientists'. As I discuss in section 5.5.1, even the illustrations in books for children incline towards objectivity, as the reader often views the illustration from the 'god-like' observer viewpoint, and objective classifying illustrations are common.

In terms of writer-solidarity with the reader the books for children are very like the textbooks, but without the formality of nominalisation, passivisation or many technical terms. Like the textbooks they are serious in tone. Importantly, like the textbooks, they identify the reader with scientists as a group. They show solidarity with the child readers in a range of ways such as questions, exclamations, vivid language and illustrations.

As might be expected considering that the textbooks in my study are intended for adults, there are a number of differences from books for children. Firstly, books for children are more literal than textbooks, and this is reflected in the greater proportion of material compared to relational processes in books for children. The textbooks also have a higher number of lexical items per clause than any of the other genres, while, as expected, on average the children's books have fewer. This means that the textbooks have the longest clauses, while the children's books have the shortest clauses. As I already mentioned, the books for children also have less nominalisation, passivisation and use fewer technical terms.

In summary, there are great similarities between science books for children and textbooks. Almost all the differences I note above reflect differences in the intended age of the readers, the textbooks I studied being intended for adults. Further comparison of science books for children with textbooks intended for children would be useful in distinguishing these two genres.

6.1.2 Ideological assumptions in scientific genres

My second research question concerns how register in representative texts from each genre illuminates the ideological assumptions of each genre. My discussion of ideology in chapter 4 (cf. section 4.6.6) considers three aspects of this question. Firstly, it considers what constitutes a fact in the four genres in my study. Secondly, it considers the different ways in which the authors of these genres (research articles, textbooks and popular articles) establish their own objectivity and the objectivity of the subject matter under discussion (research article and textbooks). Thirdly, my discussion also builds on Myers' (1989) findings concerning the power relations between research community, reader, and writer of research articles, and extends Myers' discussion to the power relations in textbooks and popular science articles

6.1.2.1 What constitutes a fact?

Myers (1989) suggests that the purpose of research articles is to persuade the research community to accept and endorse as fact the knowledge claim of the research. Latour and Woolgar (1979:147) show that a proposition becomes a fact once members of the research community begin to cite it without modality. They suggest (1979:175) that a statement stabilises as a fact when it rids itself of determinants of time and place and all reference to its producers and the production process. In section 4.2.6 I suggest that we do see this separation of facts from their origins in research article to a limited extent (limited because the necessity to cite references means that the producers of the fact and the date of publication of the research are generally recoverable). However the process of separation of facts from their origins is completed in textbooks. In general in textbooks, reference is very seldom made to scientists (producers of facts), what reference there is being almost exclusively to generic scientists. Textbooks summarise propositions that have been endorsed as fact by the research community. Textbooks, I suggest in section 4.2.6, reify the fact, making facts rather than scientists central. These facts are nonmodalised and removed not only from time, place and reference to the production process, but also from their producers. The same point can be made about science books for children.

Popular science articles, like textbooks, use research articles as their source. However, they report on the research at a different point in time compared to textbooks (cf. section 4.6.6). Textbooks wait until a proposition has been endorsed as fact by being accepted by the research community before including that proposition. Popular articles, by contrast, report on new research before the research community has had a chance to endorse or reject it as fact. Thus popular science reports on propositions rather than facts. As a result popular articles are couched in terms of modality, and the researchers, the producers of the 'fact', are stressed, as they are the authorised sources from which the writer of the popular articles draws credibility.

6.1.2.2 How objectivity is established.

As has been established (Latour and Woolgar 1979, Myers 1989), the authors of research articles and textbooks establish their objectivity by the removal of people from the account. This extends the western cultural association of reference to the personal with emotion, the polar opposite of reason and logic. A proposition that is associated with a person is likely to be viewed as that person's subjective opinion, possibly influenced by that person's emotions. If reference to people is removed, and the proposition is made impersonal, this gives an impression of objectivity and thus greater truth-value. Myers (1989) points out that personal language in research articles signals to the reader that the writer does not have proof for what is said and is thus obliged to limit it to him/herself. In section 4.2 I suggest that textbooks signal objectivity in the same way as research articles do, removing people almost entirely, with occasional mention of generic scientists only. Myers suggests that individual scientists are regarded as much less important than the research community as a whole. The suppression of individual scientists in science textbooks, to an even greater extent than in research articles, indicates that in textbooks individual scientists are not only less important than the research community as a whole (Myers 1989), but also less important than their own ideas. In textbooks the ideas of individual scientists achieve continuity with the ideas of others, becoming part of what is regarded as truth in the discipline (cf. section 4.2.6). Science books for children are very similar to textbooks in their suppression of individual in favour of generic scientists, and in their presentation of facts as a seamless continuity (cf. section 4.5.6).

A very different way of establishing objectivity is employed in popular science articles (cf. section 4.3.6). This relates to the necessity in journalism to quote authorities. In popular science articles, the scientists who have performed research are the authorities that are quoted. By quoting an authority, the writer appears objective because they are not giving their own subjective opinion, but rather the statements of a scientific authority. Further than this, in the three popular articles in my study, the writers use alternate positive and negative evaluation to structure the articles as a dialogue/debate. This strengthens the impression of writer objectivity, because it appears that the writer is standing aside from the debate and merely reporting what is said by others.

6.1.2.3 Power relations in the four genres

In any text, either the reader or the writer may be the more powerful participant, or the reader and writer may be more or less equivalent in power. In discussing such power relations in the four genres in the study, I distinguish three kinds of participant in the text: the research community (both those active and those not active in the particular problem of the research), the reader and the writer of the text. In some genres the reader or the writer may be identical with or represent the research community, while in others the research community represents a third category of participant distinct from either reader or writer.

In my study I have relied on Myers' (1989) findings that in research articles both the reader and writer are identified as members of the research community. As Myers (1989) points out, the reader of a research article represents the research community and is thus much more powerful than the writer. The writer's recognition of this is reflected in deference, in the form of solidarity politeness, shown to the reader Myers (1989) found that the writer takes account of those in the research community active in the present research question and also those who merely show an interest in the results.

In textbooks and science books for children by contrast, the writer summarises the facts that have been accepted by the research community. In doing so the writer 'speaks for', has the authority of, and thus represents the research community. In representing the research community, which, as Myers (1989) points out, is more powerful than individual scientists, the writer is more powerful than the reader, here a newcomer to the discipline.

Popular science articles assume an equal relationship between reader and writer. Both are, to varying extents, depending on the publication, projected as outside the research community. They are, in particular, outside of that part of the research community active in the immediate research problem, although in the case of popular science journals such as Scientific American, the projected reader is part of the wider scientific research community that takes an interest in the findings of other disciplines. Nevertheless, in popular science both reader and writer are, to a certain extent, uninvolved observers. That part of the research community involved in the immediate research problem reported on is, however, present in any popular article, although not as writer or projected reader. Instead, from this part of the research community are drawn the authorities, whose utterances, ideas and findings are quoted by the writer. This could be said to place the research community in a powerful position in a general sense, both adding to and drawing on the authority of science discussed by Lemke (1990). However, it cannot be said that the individual scientists are invariably treated as being in a more powerful position than both reader and writer in popular scientific texts. My analysis in sections 4.3.6 and 4.4.6 indicates that the writer of the article may make judgements about the validity of the utterances, ideas and findings of the experts/authorities concerned. Such judgements are often attributed to other scientific authorities, stressing the objectivity of the writer while still enabling him/her to make the judgements. An example from the Scientific American article in my study is:

> *A reassessment of the fossil evidence now suggests the regular extinctions said to be the handiwork of Nemesis may never have taken place.*
> *Antoni Hoffman of Columbia University contends that uncertainties in fossil dating and biases in Raup and Sepkoski's methodology cast doubt on their results.*

In fact the writer of the article may judge the scientific research community quite harshly, as reflected in the following extract from the article from the Mail and Guardian analysed in section 4.4 of my study:

> *Most right-thinking palaeontologists...*
> *Academics would naturally prefer that the explanation ...were simple. Indeed, there are those who insist there is only one explanation (namely their own).*

Thus although the scientific research community in general is viewed as a source of authoritative information (i.e. powerful relative to the writer and reader), individual scientists may be criticised and their findings judged negatively.

6.1.3 Pedagogical relevance of the research

In chapter 5 I suggest three areas of pedagogical relevance of my research. Firstly in section 5.2.2, I suggest that textbooks and research articles are target forms for university students. As a result I suggest that any inclusion of popular features (such as more reference to scientists in textbooks in order to 'humanise' them) would be ill-advised. Instead, I recommend greater use of popular texts both in teaching science at school and university level. My reasons for this recommendation are that popular science texts, because they report on scientific findings at a point before they are endorsed a fact by the research community, give an insight into the social construction of scientific knowledge. I argue in section 5.3.1 that introduction of popular texts into school and university science teaching would challenge the popular belief that science is authoritative (because, in popular science texts, scientific ideas are represented as still open to debate). It would also challenge the idea of science as difficult (because popular texts represent science as the activity of many unknown scientists rather than few very well known people like Einstein. By extension, science is not limited to the highly intelligent few, but available to a wider range of people)

The second area of pedagogical relevance of my research relates to the teaching of scientific writing, which I discuss in section 5.3.3. I suggest that in spite of register differences between popular texts and academic texts popular texts are nevertheless valuable in teaching scientific writing because they are conceptually simpler than academic texts. I argue also that asking students to 'translate' from popular to academic genres, and also to frame their scientific ideas for a non-scientific audience enables students to distinguish the popular from the academic register and thus encourages a deeper knowledge of academic scientific register.

Finally, a third area of relevance relates to science in the early years of school. Because of the many similarities between science books for children and textbooks, I have suggested (in section 5.5.2) the value of a greater role for science books for children in the early years of school.

6.2 Limitations of my study and suggestions for further research

There are two broad areas of limitation in my study, and correspondingly, two areas that would benefit from further research. The first relates to the science genres that have been omitted from study in this research, and the second relates to questions of pedagogical importance that I raised in chapter 5. I discuss each of these in turn in what follows.

The most important limitation on my research is the restricted range of popular science genres it explores. Only two print media genres are explored: the issues report and the opinion piece. Popular science genres are more diverse than this limited selection. In popular science journals, for example, there are at least three different sorts of text:

- The short news items (issues report) examined in this study (the Scientific American article).
- Long articles written by researchers popularising their own research.
- Long articles written by science journalists.

These are likely to differ in a number of ways. For example one difference found by Garcés-Conejos and Sánchez-Macarro (1998) is that long popularisations written by the original researchers take account of the two audiences mentioned by Myers in connection with research articles. These are readers not active in the discipline but who take an interest in the research (esoteric audience) as well as researchers in the discipline (exoteric audience). By contrast, the news articles found in this study take account only of readers not active in the discipline. Researchers active in the discipline appear in such news articles only as the authoritative sources quoted by the writer. It is also likely that long articles are different in genre from short news articles.

Besides these different kinds of popular science articles in popular journals, newspapers and newsmagazines, there are at least four other genres of science popularisations. These include factual and narrative genres, both written and filmed:

1. Factual books

- Full-length books such as Stephen Hawking's *A Brief History of Time*.

2. Narrative books

- Written narratives about science and scientists. Examples are narratives about monsters such as *Frankenstein*, *Dr Jeckyll and Mr Hyde* etc., and science fiction.

3. Documentary/factual films

- Filmed documentaries on Nature/wildlife (for example BBC *Life on Earth)*, which film and describe the behaviour and life of animals in the wild. The focus is largely animals (usually mammals), although plants may be included on occasion.
- Documentaries on technology (for example the Australian *Beyond 2000)*, which describe innovations which are potentially useful in modern western society.
- Documentaries on conservation (for example the South African *50/50*), which, distinguishable from documentaries on Nature in that they focus on the interface between development and technology on the one hand, and conservation on the other, and describe the way that human communities impinge, usually negatively, on animals (and plants).
- Factual television programmes explaining science to children (e.g. *Bill Nye the Science Guy*)

4. Filmed Narrative

- Narrative film genres on the topic of science and scientists. Examples are disaster films such as *Meteor*, *Deep Impact*, and *Tornado* and 'monster' films such as *Jurassic Park*.
- Television dramas, for example about forensic scientists (e.g. *Quincy* and *CSI*)
- Cartoon representations of scientists such as *Pinkie and Brain*.
- Television genres for adolescents (for example how is science represented in dramas about teenagers in school?).

Thus an area for future research is analysis of some of these genres. Of particular interest to me would be an examination of ideology in the filmed genres, which I speculate have a wider audience than the written genres. This would provide insight into public attitudes to science and scientists, which I believe have a major impact on how accessible science is. Representations in written and filmed narratives of science as boring (e.g. in teen dramas), and of scientists as sinister (Mr Hyde), unfeeling (e.g. one of the forensic scientists in *CSI*), or 'nerdy' (e.g. in teen drama) make science unattractive. Such representations function similarly to the ideologies of science as difficult and authoritative (Lemke 1990) in making science difficult to learn. Study of documentaries and written and filmed narratives would, I believe, allow deeper understanding of negative conceptions of science and could be useful in widening access to science.

With respect to science books for children, my study has focused on texts of the information report genre (considered from the perspective of Australian genre studies). This neglects exploration of other genres in science books for children such as procedure (e.g. how to germinate bean seeds) and explanation (e.g. how a tap works). These are also common in books for children, and would provide a fuller picture of the extent of similarity between books for children and textbooks.

A second area for future research concerns two questions of pedagogical importance that I raise in section 5.5.2. The first of these questions is that originally posed by Martin (1989) of whether factual writing is actually inherently more difficult for children than narrative, or whether it is experienced as more difficult because it is less familiar. This might require ethnographic study of the literacy practices of individual families who stress factual as well as narrative genres. Alternatively, study of the experiences of children in schools that stress factual genres might be valuable.

A second question of pedagogical importance relates to my suggestion in section 5.2.2 that the major kinds of assessed writing that science students do – namely, exam answers and lab reports - are similar to and modelled on textbooks and research articles respectively. The similarity of these genres of student writing to textbooks and research articles would benefit from further research, as this has implications for the teaching of academic literacy to science students. As my brief analysis of a biochemistry student lab report in section 5.2.2 shows, there are differences in the discourse features of student lab reports and research articles. These are based on the different purposes of these two genres. The purpose of the research article is to gain recognition of a new knowledge claim while the purpose of a student lab report is to demonstrate to the staff member concerned that the laboratory work was carefully done, that reasonably accurate results were obtained and that anomalous results are adequately explained. Thus the two genres have different readers, and only the research report is expected to report on new information.

In summary, areas mentioned in this thesis that would benefit from further research include, firstly, a range of written and filmed genres of popular science. Secondly, a pedagogically important question in need of further research includes the question of whether factual writing is inherently more difficult than narrative. Finally, of pedagogical relevance too is further study of the differences between student writing (exam answers and lab reports) on the one hand, and textbooks and research articles on the other.

6.3 Summary and Conclusion

This thesis indicates the value of a study of popular science genres for an understanding of popular conceptions of science. It demonstrates the relationship between research articles and popular articles, with research articles being the source of information for popular articles at a moment in time before the knowledge claims of the research article are either accepted as fact or rejected. It notes therefore that one valuable function of popular science articles is in affording readers a view of 'science in the making', rather than science as incontrovertible fact. Also, because they are peopled with large numbers of human participants, (almost entirely scientists who were not previously known to the reader), popular science articles afford a view of science which is relatively widely accessible in that it is available even to those who are not iconic figures like Einstein. Thus popular science articles are of value in 'humanising' science. This thesis indicates too that further study, particularly of filmed and narrative science genres, would deepen our understanding of popular ideologies of science, particularly the little-studied ideologies of science as boring and scientists as sinister. Such studies might be of use in widening access to science.

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Contents of Appendix

Raup, D.M. and Sepkoski, J. (1984) Periodicity of extinctions in the geologic past *Proc. Natl. Acad. Sci.* 81:801-805.

Periodicity of extinctions in the geologic past

Abstract [1a]The temporal distribution of the major extinctions over the past 250 million years has been investigated statistically [1b]using various forms of time series analysis. [2a]The analysed record is based on variation in extinction intensity for fossil families of marine vertebrates, invertebrates, and protozoans [2b]and contains 12 extinction events. [3]The 12 events show a statistically significant periodicity ($P < 0.01$) with a mean interval between events of 26 million years. [4]Two of the events coincide with extinctions that have previously been linked to meteorite impacts (terminal Cretaceous and Late Eocene). [5a]Although the causes of the periodicity are unknown, [5b]it is possible that they are related to extraterrestrial forces (solar, solar system, or galactic).

[6a]Virtually all species of animals and plants that have ever lived are now extinct, [6b]and the known fossil record documents some 200,000 such extinctions. [7a]It has been generally assumed that extinction is a continuous process [7b]in the sense that species are always at risk [7c]and that mass extinctions simply reflect relatively short-term increases in that risk. [8]Following this view, the extinction process is often described as a time homogeneous process using standard birth-death models (1-3). [9]There is increasing evidence, however, that many extinctions are actually short-lived events of special stress, separated by periods of much lower, or even negligible, risk. [10a]Fischer and Arthur (4) departed from convention [10b]by arguing that [10c]major extinction events of the past 250 million years (ma) occurred periodically at nearly constant intervals of 32 ma [10d](see also ref. 5). [11a]Their study used a limited data base, [11b]and no statistical testing was done. [12a]The purpose of this paper, therefore, is to test the proposition of periodicity in the record of marine extinctions over the past 250 ma (Late Permian to recent) [12b]by using as rigorous a methodology as present data permit.

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(paragraph 27)

Best fit cycle. [13]*The results of a final test of the extinction record are illustrated in* Fig. 4. [14]This figure represents a "composite cycle" constructed by averaging together 26-ma segments of the time series in Fig 1. [15a]To compute the composite, [15b]the time series was marked off at 26-ma intervals [15c]in such a way that the Cretaceous-Tertiary boundary peak (at 65 ma B.P.) was at the center of one interval. [16a]The extinction data in each interval (interpolated to every 1ma) were then rescaled [16b]so that the maximal value was100%. [17a]These values were collected with their counterparts in other intervals [17b]and averages and dispersions were calculated.

[18]This procedure was performed for a variety of interval lengths (i.e. cycle lengths) on either side of 26ma. [19a]The illustrated composite cycle represents a best-fit to the data [19b]in the sense that the composite peak has maximal amplitude and minimal dispersion about the median values. [20a]Tests of the medians show highly significant differences: [20b]a Friedmann's test for points separated by 6 ma (the approximate average stage duration) results in an S value of 250 (P<0.05 with four degrees of freedom). [21a]Other cycle lengths give less significant results [21b]and the composite curve deteriorates

Proc. Natl. Acad. Sci. USA
Vol. 81, pp. 801–805, February 1984
Evolution

Periodicity of extinctions in the geologic past

(evolution/time series/paleontology)

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Contributed by David M. Raup, October 11, 1983

ABSTRACT **The temporal distribution of the major extinctions over the past 250 million years has been investigated statistically using various forms of time series analysis. The analyzed record is based on variation in extinction intensity for fossil families of marine vertebrates, invertebrates, and protozoans and contains 12 extinction events. The 12 events show a statistically significant periodicity ($P < 0.01$) with a mean interval between events of 26 million years. Two of the events coincide with extinctions that have been previously linked to meteorite impacts (terminal Cretaceous and Late Eocene). Although the causes of the periodicity are unknown, it is possible that they are related to extraterrestrial forces (solar, solar system, or galactic).**

Virtually all species of animals and plants that have ever lived are now extinct, and the known fossil record documents some 200,000 such extinctions. It has been generally assumed that extinction is a continuous process in the sense that species are always at risk and that mass extinctions simply reflect relatively short-term increases in that risk. Following this view, the extinction process is often described mathematically as a time homogeneous process using standard birth-death models (1–3). There is increasing evidence, however, that many extinctions are actually short-lived events of special stress, separated by periods of much lower, or even negligible, risk. Fischer and Arthur (4) departed from convention by arguing that the major extinction events of the past 250 million years (ma) occurred periodically at nearly constant intervals of 32 ma (see also ref. 5). Their study used a limited data base, and no statistical testing was done. The purpose of this paper, therefore, is to test the proposition of periodicity in the record of marine extinctions over the past 250 ma (Late Permian to Recent) by using as rigorous a methodology as present data permit.

DATA BASE

The data for this study come from Sepkoski's compilation (6) of the temporal ranges of ≈3,500 families of marine animals (vertebrate, invertebrate, and protozoan), but the subset of data and method of expressing extinction intensity differ from our previous analyses of these data (7, 8). For the present study, a culled subset of the total sample was used: all families with low-resolution ranges, not known to the level of the stratigraphic stage, were eliminated, as were families noted by Sepkoski (6) as having questionable taxonomic or stratigraphic designations. In addition, families still living today were ignored in order to avoid the damping effect of the "Pull of the Recent" (9). This culling process reduced the sample substantially (567 for the Late Permian to Recent) but in so doing removed much of the noise that characterizes data sets of this kind.

The Late Permian to Recent interval analyzed in this study contains several well-documented mass extinctions, has a comparatively accurate time scale, and is divided into relatively short stratigraphic stages. The interval comprises 39 international stages ranging in age from 253 ma B.P. (base of the Dzhulfian Stage of the Late Permian) to 11.3 ma B.P. (top of the Middle Miocene), using the Harland time scale (10). The mean duration of these 39 stages is 6.2×10^6 years, which makes it impossible to resolve extinction events separated by less than about 12×10^6 years (the Nyquist rate). Although finer resolution is possible in some parts of the geologic column and with some biologic groups, the resolution used in the present study is the best that can be achieved for comprehensive analysis in the present state of synoptic work.

One can debate the quality of the individual data. The family is a rather large and arbitrary taxonomic unit and as such tends to damp variation at the species level (11): even if 99% of the members of a family become extinct at one time, the persistence of a single species will prevent that family from reflecting the extinction event. However, in spite of this problem, patterns of familial diversification and extinction do seem to correlate well with data for fossil species (12), and the available data for families represent a far more uniform and less biased sampling of the fossil record than any species-level data set.

Age designations in the data set are also open to question, especially because geologic time scales are continually being revised. A given time scale represents a merger of a chronostratigraphic sequence (based primarily on fossils) and a scattering of radiometric dates (13). The present analysis uses the Harland and Odin time scales (10, 14), which have some substantial differences. The Harland scale is quite similar to that of Armstrong (15) and is nearly identical to the new time scale of the Geological Society of America (16). Thus, the Harland scale is probably the closest to a consensus, even though problems remain.

MEASUREMENT OF EXTINCTION RATES

Many metrics have been used to express variation in the intensity of extinction. Most commonly, the number of extinctions in an interval of geologic time is divided by standing diversity (total taxa present) and this in turn is divided by the estimated duration of the interval to yield a normalized, per capita rate of extinction per million years. In the present analysis, we have not normalized for time because of considerable uncertainty in the durations of stages (for example, the correlation of post-Paleozoic stage durations between the Harland and Odin time scales is only 0.48) and because of the growing suspicion, mentioned above, that extinction is not a continuous process (see also ref. 17). Furthermore, it should be noted that there is no statistical correlation between the raw extinction data and stage duration: for the stages of the Phanerozoic used by Sepkoski (6), numbers of extinctions have a correlation of −0.06 with stage durations in the Harland time scale. This is compatible with the hypothesis that extinction is an episodic process.

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Abbreviation: ma, million year(s).

into an irregular, non-unimodal curve (noise) [21c]when the cycle departs substantially from the best-fit cycle.

[22a]It should be noted that the composite curve in Fig 4 rises to a fairly sharp peak, [22b]which is compatible with ([22c]although does not prove) the proposition that mass extinctions are discrete events. [23a]If extinctions resulted from continuous fluctuations in background rate, [23b]a composite curve approaching a sine-cosine function would be expected. [24a]The curve in Fig. 4 may in fact represent a rather conservative illustration of the abruptness of the average extinction peak; [24b]much of its breadth may result from the interval nature of the data and the fact that sampling error (i.e. failure to locate a family's precise interval of extinction) tends to smear the record of mass extinction backward in time (20). [25]The slight asymmetry of the curve in Fig 4 is consistent with this last proposition.

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[26a]If periodicity of extinctions in the geologic past can be demonstrated, [26b]the implications are broad and fundamental. [27]A first question is whether we are seeing the effects of a purely biological phenomenon or whether periodic extinction results from recurrent events or cycles in the physical environment. [28a]If the forcing agent is in the physical environment, [28b]does this reflect an earthbound process or something in space? [29a]If the latter, [29b]are the extraterrestrial influences solar, solar system, or galactic? [30a]Although none of these alternatives can be ruled out now, [30b]we favour extraterrestrial causes [30c]for the reason that purely biological or earthbound physical cycles seem incredible, [30d]where the cycles are of fixed length [30e]and measured on a timescale of millions of years. [31a]By contrast, astronomical and astrophysical cycles of this order are plausible [31b]even though candidates for the particular cycle observed in the extinction data are few. [32a]One possibility is the passage of our solar system through the spiral arm of the Milky Way Galaxy, [32b]which has been estimated to occur on the order of 10^8 years (21). [33a]Shoemaker has argued (21) that [33b]passage through galactic arms should increase the comet flux [33c]and this could, following the Alvarez hypothesis (22) provide an explanation for the biological extinctions. [34]Two of the extinction events (Late Cretaceous and Late Eocene) are associated with evidence for meteorite impact (23, 24). [35a]However much more information is needed [35b]before definitive statements about causes can be made. [36]It may turn out that the biological record is sensitive to periodic phenomena that other indicators have failed to recognise.

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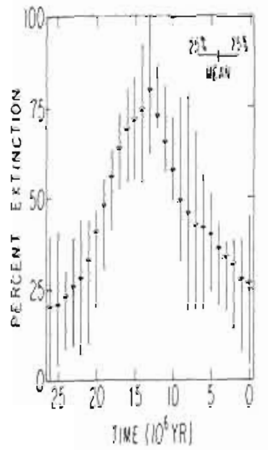

FIG. 4. Composite best-fit curve for extinction intensity using a 26-ma cycle. The range between the 25th and 75th percentiles of the data is shown by the vertical lines.

scale are highly significant. This does not apply to the analysis based on the Odin time scale; the $P < 0.05$ point at 26 ma is corroborative but not significant.

The analysis just described lessens confidence in the scattered indications of periodicity outside the 25- to 27-ma range in Table 1. The significant cycles at 19, 29, and 30 should be interpreted only as suggestions for future exploration when stronger data bases are available. The cycle at 30 ma may be real but cannot be confirmed with the present time series.

Best-Fit Cycle. The results of a final test of the extinction record are illustrated in Fig. 4. This figure represents a "composite cycle" constructed by averaging together 26-ma segments of the time series in Fig. 1. To compute the composite, the time series was marked off at 26-ma intervals in such a way that the Cretaceous-Tertiary boundary peak (at 65 ma B.P.) was at the center of one interval. The extinction data in each interval (interpolated to every 1 ma) were then rescaled so that the maximal value was 100%. These values were collected with their counterparts in other intervals and averages and dispersions were calculated.

This procedure was performed for a variety of interval lengths (i.e., cycle lengths) on either side of 26 ma. The illustrated composite cycle represents a best-fit to the data in the sense that the composite peak has maximal amplitude and minimal dispersion about the median values. Tests of the medians show highly significant differences: a Friedmann's test for points separated by 6 ma (the approximate average stage duration) results in an S value of 250 ($P < 0.05$ with four degrees of freedom). Other cycle lengths give less significant results, and the composite curve deteriorates into an irregular, non-unimodal curve (noise) when the cycle departs substantially from the best-fit cycle.

It should be noted that the composite curve in Fig. 4 rises to a fairly sharp peak, which is compatible with (although does not prove) the proposition that mass extinctions are discrete events. If extinctions resulted from continuous fluctuations in background rate, a composite curve approaching a sine-cosine function would be expected. The curve in Fig. 4 may in fact represent a rather conservative illustration of the abruptness of the average extinction peak: much of its breadth may result from the interval nature of the data and the fact that sampling error (i.e., failure to locate a family's precise interval of extinction) tends to smear the record of mass extinction backward in time (20). The slight asymmetry of the curve in Fig. 4 is consistent with this last proposition.

CONCLUSIONS

The time series in Fig. 1 has the 26-ma cycle superimposed in its best-fit position. The deviations from this best-fit position are listed in Table 2. The 26-ma cycle predicts 10 extinction events in the Permian–Miocene interval, whereas the actual time series contains 12 peaks. Of the 12 peaks, the smallest is in the Early Triassic (Olenekian): this peak reflects only ammonoid extinctions and may be spurious, but it was included in the analysis for the sake of consistency. The poorest fits are for 2 peaks in the Middle Jurassic and the one in the Early Cretaceous. These three peaks are low and may not be significantly higher than the surrounding background extinction.

It seems inescapable that the post-Late Permian extinction record contains a 26-ma periodicity, assuming that the Harland time scale (with its Geological Society of America com-

Table 2. Comparison of geologic ages of observed extinction peaks and the predicted ages of a 26-ma cycle in best-fit position

	Harland time scale			Odin time scale		
	Peak observed, ma B.P.	Closest peak predicted, ma B.P.	Error, ma	Peak observed, ma B.P.	Closest peak predicted, ma B.P.	Error, ma
Tertiary						
Middle Miocene	11.3	13	−1.7	11	9.4	+1.6
Late Eocene	38	39	−1	34	35.4	−1.4
Cretaceous						
Maestrichtian	65	65	0	65	61.4	+3.6
Cenomanian	91	91	0	91	87.4	+3.6
Hauterivian	125	117	+8	114	113.4	+0.6
Jurassic						
Tithonian	144	143	+1	130	139.4	−9.4
Callovian	163	169	−6	150	139.4	+10.6
Bajocian	175	169	+6	170	165.4	+4.6
Pliensbachian	194	195	−1	189	191.4	−2.4
Triassic						
Norian	219	221	−2	209	217.4	−8.4
Olenekian	243	247	−4	239	243.4	−4.4
Permian						
Dzhulfian	248	247	+1	245	243.4	+1.6
	Standard deviation of errors = 3.58			Standard deviation of errors = 5.65		

ε·art) is a reasonable approximation of reality. This conclusion is based primarily on the nonparametric test procedure described in this paper, but the other, less rigorous tests are largely confirmatory, especially the best-fit composite cycle (at 26 ma, Fig. 4). Of particular importance is the fact that the nonparametric test gives approximately the same results when applied independently to the two halves of the time series. The Fourier and autocorrelation analyses yield cycles reasonably close to 26 ma. In view of the various sources of distortion in these analyses, we do not see these discrepancies as significant. It is likely, however, that as the quality of the time scale and paleontological data improve, the length of the estimated cycle may shift somewhat.

It is possible that the appearance of a 26-ma cycle actually results from a longer cycle of, say, 52 ma in combination with a scattering of random events. This model has been tested and found to be a weaker description of the data than the simple 26-ma cycle.

Also, with more and better data, studies of periodicity can be extended to the Paleozoic. At present, the Sepkoski data set shows no evidence of Paleozoic periodicity that can survive the test procedures used here for the younger record. This may well be due to the relatively weak state of the Paleozoic time scale but nothing can be said unequivocally at this time.

IMPLICATIONS

If periodicity of extinctions in the geologic past can be demonstrated, the implications are broad and fundamental. A first question is whether we are seeing the effects of a purely biological phenomenon or whether periodic extinction results from recurrent events or cycles in the physical environment. If the forcing agent is in the physical environment, does this reflect an earthbound process or something in space? If the latter, are the extraterrestrial influences solar, solar system, or galactic? Although none of these alternatives can be ruled out now, we favor extraterrestrial causes for the reason that purely biological or earthbound physical cycles seem incredible, where the cycles are of fixed length and measured on a time scale of tens of millions of years. By contrast, astronomical and astrophysical cycles of this order are plausible even though candidates for the particular cycle observed in the extinction data are few. One possibility is the passage of our solar system through the spiral arms of the Milky Way Galaxy, which has been estimated to occur on the order of 10^8 years (21). Shoemaker has argued (21) that passage through galactic arms should increase the comet flux and this could, following the Alvarez hypothesis (22), provide an explanation for the biological extinctions. Two of the extinction events being considered here (Late Cretaceous and Late Eocene) are associated with evidence for meteorite impact (23, 24). However, much more information is needed before definitive statements about causes can be made. It may turn out that the biological extinction record is sensitive to periodic phenomena that other indicators have failed to recognize.

The implications of periodicity for evolutionary biology are profound. The most obvious is that the evolutionary system is not "alone" in the sense that it is partially dependent upon external influences more profound than the local and regional environmental changes normally considered. Much has been written about the "bottlenecking" effect of mass extinction. With kill rates for species estimated to have been as high as 77% and 96% for the largest extinctions (11, 25), the biosphere is forced through narrow bottlenecks and the recovery from these events is usually accompanied by fundamental changes in biotic composition (26). Without these perturbations, the general course of macroevolution could have been very different.

We thank Eric W. Holman, Ronald Thisted, and D. S. Simberloff for discussions of statistical procedures. This research was supported by National Aeronautics and Space Administration Grant NAG 2-237.

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[1]The stratigraphic use of fossils for purposes of correlating rocks from one area to another may proceed without any theoretical interpretation of the nature of evolution. [2]But for the last two centuries the factors controlling biological change have been the subject of debate marked by a distinct dichotomy of views. [3]Perhaps the simplest interpretation of the extinction of faunal and floral assemblages, and one favoured early in the nineteenth century by French geologists in particular, was that of extinction by catastrophe. [4]On the other hand, with the emergence of evolution as a dominating idea in biological change, catastrophism was challenged by notions of gradualism. [5a]Diverse forms were thought [5b]to arise from ancestral stocks by gradual changes imposed by physical conditions and biological competition; [5c]unsuccessful forms died out over variable periods of time. [6a]Wherever there were gaps in the fossil record with sudden changes in fossil content, [6b]it was maintained that this was due either to lack of preservation or inadequate collecting or both.

[7a]Palaeontological researches have proceeded with ever-increasing intensity throughout this century, [7b]but in spite of these efforts many of the gaps marking sudden extinctions followed by sudden increases in the number of forms (referred to as radiations) still remain. [8]Thus the major boundaries in the stratigraphic column (see Table 7.1) have been reinforced e.g. the decline of the Cambrian faunas and the Ordovician radiation; the decimation of the Palaeozoic faunas and floras at the end of the Permian period; dinosaurs and other Mesozoic forms superceded by the mammalian faunas of the Tertiary. [9]Linked with modern support for catastrophism is a process which has been called punctuated evolution. [10a]Long periods of little change in widespread forms are ended by mass extinctions [10b]and the vacated ecological niches are then taken over by forms which have diversified in relatively isolated areas.

[11]Much attention has been paid to the Cretaceous/Tertiary (K/T) boundary. [12]At a number of places throughout the world, including the oceans, where sedimentation was continuous through the boundary, examination of clays has shown some chemical and mineralogical peculiarities. [13]In particular the boundary is marked by an enrichment in the element, iridium. [14]The significance of this anomaly lies in the fact that this element is more abundant in planetismals than in the Earth. [15a]So it is maintained that the Earth was hit by an extra-terrestrial body, [15b]the catastrophic and climate effects being the reason for much of contemporary life, for example, large foraminifera in the oceans, and on land the dinosaurs, becoming extinct. [16a]The topic is still hotly debated; [16b]it is pointed out that excessive volcanism, perhaps associated with the outpourings of the lavas of the Deccan Traps in India at that time, would have climatic effects to which some organisms could not adapt. [17]Some palaeontologists while accepting the reality of different rates of evolution would resist catastrophism and instantaneous extinctions. [18a]With regard to the dinosaurs and the K/T boundary many would maintain [18b]that these reptiles had been gradually dying out for some time during the Cretaceous. [19]On the other hand the case for mass extinctions by catastrophe involving not the survival of the fittest but the survival of the luckiest has been developed recently in a stimulating and provocative account *Wonderful Life* by the American Writer S.J. Gould.

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Table 7.1 Classification of geological Eras and Periods

Distinctive life of the geological periods

Era	Period	Distinctive life
CENOZOIC	Recent	Modern man
	Pleistocene	Stone Age man
	Pliocene	Great variety of mammals Elephants widespread
	Miocene	Flowering plants in full development Ancestral dogs and bears
	Oligocene	Ancestral pigs and apes
	Eocene Paleocene	Ancestral horses, cattle and elephants appear
MESOZOIC	Cretaceous	Extinction of dinosaurs and ammonites Mammals and flowering plants slowly appear
	Jurassic	Dinosaurs and ammonites abundant Birds and mammals appear
	Triassic	Flying reptiles and dinosaurs appear First corals of modern types
PALAEOZOIC	Permian	Rise of reptiles and amphibians Conifers and beetles appear
	Carboniferous	Coal forests First reptiles and winged insects
	Devonian	First amphibians and ammonites Earliest trees and spiders Rise of fishes
	Silurian	First spore-bearing land plants Earliest known coral reefs
	Ordovician	First fish-like vertebrates Trilobites and graptolites abundant
	Cambrian	Trilobites, graptolites, brachiopods, molluscs, Crinoids, radiolaria, foraminifera Abundant fossils first appear
	Late Precambrian	Scanty remains of primitive invertebrates, sponges, worms, algae, bacteria
	Earlier Precambrian	Rare algae and bacteria back to at least 3000 m.y. for oldest known traces of life

The Stratigraphical sequence

Eras	Periods and systems	Derivation of names	Age ($\times 10^6$ years)
CENOZOIC *Kainos* or *Cenos* = recent *Zoe* = life (Recent life)	QUATERNARY Recent *or* Holocene	*Holos* = complete, whole	
	Glacial *or* Pleistocene	*Pleiston* = most	-2
	TERTIARY Pliocene	*Pleion* = more	
	Miocene	*Meion* = less (i.e. less than in Pliocene)	
	Oligocene	*Oligos* = few	
	Eocene	*Eos* = dawn	
	Paleocene	*Palaios* = old	
	The above comparative terms refer to the proportions of modern marine shells occurring as fossils		-66
MESOZOIC *Mesos* = middle (Mediaeval life)	CRETACEOUS	*Creta* = chalk	-144
	JURASSIC	*Jura* Mountains	-208
	TRIASSIC	*Threefold* division in Germany	
	(New Red Sandstone = desert sandstones of the Triassic Period and part of the Permian)		-245
PALAEOZOIC *Palaios* = ancient (Ancient life)	UPPER PALAEOZOIC PERMIAN	*Permia*, ancient kingdom between the Urals and the Volga	-286
	CARBONIFEROUS	*Coal* (carbon)-bearing	-360
	DEVONIAN (Old Red Sandstone = land sediments of the Devonian Period)	*Devon* (marine sediments)	-408
	LOWER PALAEOZOIC SILURIAN	*Silures*, Celtic tribe of Welsh Borders	-438
	ORDOVICIAN	*Ordovices*, Celtic tribe of North Wales	-505
	CAMBRIAN	*Cambria*, Roman name for Wales	-570
	PRECAMBRIAN ERAS *PROTEROZOIC	*Proteros* = earlier	-2500
	*ARCHAEOZOIC or ARCHEAN	*Archaeos* = primaeval	
	The time between the formation of the Earth (4600 m.y.) and the oldest dated Archean rocks (3800 m.y.) is referred to as Pre-archean		

* These are sometimes differentiated as EONS together with PHANEROZOIC ('life appearing') which comprises Cambrian to the present.

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[1]Extraterrestrial Mechanisms

[2]Intrasolar

[3]Perhaps the most interesting and controversial proposal made in palaeobiology in the last decade is the proposal that the Late Cretaceous mass extinction was triggered by the impact of a large asteroid (Alvarez et al 1980), perhaps half the size of the Martian moon Phobos (Figure 2.6), itself believed to have originated in the asteroid belt between Mars and Jupiter. [4a]There is an entire class of asteroid-sized bodies, the Apollo objects, which have orbits which cross that of the Earth [4b]and it is only a matter of time before a collision takes place. [5]Thus it is entirely reasonable to propose that such an event has taken place in the past, and that the catastrophic results of such a collision could trigger global ecosystem collapse. [6]In retrospect, it is the very catastrophic and geologically instantaneous nature of such a proposal which has led to rejection of the idea by many, who see the proposal as a return of nineteenth-century catastrophism. [7]On the other hand, others have gone to the extreme of maintaining that *all* mass extinctions are triggered by impacts, and that these impacts occur with clock-like regularity.

[8]An impressive body of evidence has been amassed which supports the idea that an asteroid did indeed impact the Earth at the end of the Maastrichtian Age in the Late Cretaceous. [9]The initial evidence was geochemical – the discovery of anomalously high concentrations of the element iridium in the sediments of the latest Maastrichtian Age. [10a]Iridium is depleted in crustal rocks of the Earth, [10b]but enriched in meteoritic materials. [11]The anomalous iridium layer has now been discovered at sites all over the globe, and in both marine and terrestrial sediments. [12]Thus it appears that the Earth was enveloped in a dust cloud, anomalously enriched in iridium, at the end of the Cretaceous.

[13]Other evidence includes the discovery of minerals with shock features, characteristic of impacts, in sediments of latest Maastrichtian Age in widely separated regions of the globe. [14]Small spherules, argued to be impact-melt-derived, have been discovered in these same sediments as well as carbon concentrations, interpreted as the soot fallout of massive wildfires triggered by the impact. [15]Geochemical anomalies, in addition to iridium, have also been interpreted as extraterrestrial in origin.

[16]The climate effects of an asteroid or cometary impact are difficult to predict. [17]Large amounts of debris from the vaporised bolide and impact site would be injected into the atmosphere. [18a]Meteorological models suggest [18b]that such a global dust cloud would result in the total blockage of sunlight from the Earth's surface for weeks, and light intensities too low to support photosynthesis for several months. [19]Other proposed effects include poisoning of the atmosphere with nitrous oxides and cyanide, global acid rain, and destruction of the ozone layer.

[20a]Certainly such a climatic upheaval would have a major effect on the biosphere, [20b]and global temperature decline is consistent with the ecological signature of most mass

Figure 2.6. The Martian moon Phobos, photographed from 611 km away by Viking Orbiter I. Phobos is most likely an asteroid, captured by Mars from the asteroid belt, and the surface shown here (19 km by 22 km) is approximately twice the size of the asteroid which is proposed to have impacted the Earth at the end of the Cretaceous. (Photograph courtesy of NASA.)

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[24a]It has been suggested that the stepwise or protracted pattern of species extinction as seen in the fossil record is an artifact. [25a]Many extinction intervals also correlate with regressions [25b]and marine regression has a strong distorting effect on the stratigraphic record. [26a]The progressive loss of sampling area produced by regressing seas, combined with the erosion and destruction of previously deposited strata, can smear last appearances of species backwards in time [26b]and transform even an instantaneous diversity drop into a progressive diversity decline (Signor and Lipps 1982). [27a]The magnitude of this distortion can be estimated to some extent [27b]by noting the number of 'Lazarus species' (species which disappear during the extinction interval but are known to survive as they reappear later) associated with the event (Jablonski 1986a). [28a]If the Lazarus effect is strong for a particular event, [28b]then it is not possible to reject the hypothesis that the event was sudden and only artificially appears protracted. [29a]Jablonski (1986a) noted [29b]that the Lazarus effect appears worst for the Late Permian event, [29c]and raised the interesting possibility that this most severe of all crises in Earth history may have been more abrupt than is normally considered.

[30a]The stratigraphic record of many crisis intervals is sufficiently complete [30b]to negate the possibility of simultaneous extinction of all species which disappear during the event. [31a]Accepting the stepwise extinction pattern as real, [31b]an alternative impact hypothesis has been proposed (Hut et al 1987) in which a series of smaller impacts, distributed over a geologically significant period of time, is argued to have produced the sequential extinctions!

[32]Lastly, it should be noted that the climatic predictions of the impact hypothesis are strongly model-dependant. [33a]The climatic effects of large-body collision could be more long-term than currently predicted, [33b]and may produce global changes on a time scale of tens of thousands of years. [34]Such long-term climatic effects would be more in concert with the pattern of species extinctions seen in the fossil record.

[35]To date a strong case cannot be made for large impacts during crisis intervals other than the Late Cretaceous and Late Eocene events (Donovan 1987; Kerr 1987), and perhaps a small impact in the Pliocene (Kyte et al 1988). [36a]The Late Eocene is particularly interesting, [36b]in that an iridium anomaly as well as microtektites have been found, [36c]clearly indicating extraterrestrial impact. [37a]The microtektites, however, occur in several horizons of Late Eocene and Early Oligocene age, [37b]thus evidencing a series of impacts over this time interval. [38a]Curiously, none of these multiple horizons appears to correspond exactly to known extinction horizons (Keller et al 1983), [38b]thus providing no strong causal link between the extinctions and the impacts. [39a]Small iridium anomalies

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have been reported for the Cenomanian and Middle Miocene events, [39b]but an impact origin for these has yet to be conclusively demonstrated. [40]On the other hand, iridium-enrichment horizons have been discovered which were produced by sediment geochemical and biological processes. [41]Thus anomalous concentrations of iridium can no longer be taken as direct evidence for extraterrestrial impacts.

[42]Other possible intra-solar mechanisms to trigger terrestrial crises include possible fluctuations in the luminosity of the Sun, and known orbital variations in the distance of the Earth from the Sun. [43a]The possibility that the solar 'constant' varies is interesting, [43b]but difficult to demonstrate on the basis of terrestrial data alone. [44]Obviously any increase or decrease in energy from the Sun reaching the Earth would have major effects on global climate. [45]Orbital changes in Earth-Sun relationships can also cause variations in solar energy reaching the Earth. [46a]Such changes are of particular interest [46b]in that they are periodic, [46c]but the fluctuations in the Earth's orbital (Milankovitch) periods fall in the range of thousands to hundreds of thousands of years. [47a]Geological periodicities of the order 2-7 Myr, [47b]which may be orbital-related, [47a cont.]have been proposed [47c]but not confirmed [47a cont.](Rampino and Stothers 1987). [48]None match the proposed 26 Myr periodicity in Mezozoic-Cenozoic extinctions.

It has been suggested that the stepwise or protracted pattern of species extinction seen in the fossil record is an artifact. Many extinction intervals also correlate with regressions, and marine regression has a strong distorting effect on the stratigraphic record. The progressive loss of sampling area produced by regressing seas, combined with the erosion and destruction of previously deposited strata, can smear last appearances of species backwards in time and transform even an instantaneous diversity drop into a progressive diversity decline (Signor and Lipps 1982). The magnitude of this distortion can be estimated to some extent by noting the number of 'Lazarus species' (species which disappear during the extinction interval but are known to survive, as they reappear later) associated with the event (Jablonski 1986a). If the Lazarus effect is strong for a particular event, then it is not possible to reject the hypothesis that the event was sudden and only artificially appears protracted. Jablonski (1986a) noted that the Lazarus effect appears worst for the Late Permian event, and raised the interesting possibility that this most severe of all crises in Earth history may have been more abrupt than is normally considered.

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[1]Mass Extinctions and the Rate of Evolution

[2]Under normal circumstances, the rate of extinction seems to be such that roughly 10 to 20% of the species at any given time will be extinct in a matter of 5 or 6 million years. [3]The fossil record shows, however, that not all extinctions are "normal." [4]Rare catastrophic events in the past have caused large numbers of species to become extinct suddenly. [5]These events are called **mass extinctions**.

[6]The best known of these mass extinctions is the one in which the dinosaurs perished some 65 million years ago, at the end of the Cretaceous period, which was at the end of the Mesozoic era. [7]In that extinction, about two-thirds of all living species disappeared. [8]In some cases, as with ocean plankton, this number may have climbed as high as 98%. [9]But the extinction at the end of the Mezozoic was neither the largest nor the most recent mass extinction. [10]About 250 million years ago, near the end of the Palaeozoic era, about 80% of existing species disappeared in a single extinction event. [11]A somewhat milder extinction, which wiped out 30% of existing species, appears to have taken place about 11 million years ago. [12]In fact, geologists who study the past history of life in detail distinguish as many as 11 of these mass extinctions.

[13]One of the most interesting explanations for how these mass extinctions could occur was put forward in 1980 by the father-and-son team of Walter Alvarez (a geologist) and Luis Alvarez (a Nobel laureate in physics). [14a]Based on evidence they accumulated, [14b]they suggested [14c]that the impact of a large asteroid killed off the dinosaurs and other life forms. [15]Such an impact would have raised a dust cloud that would have blocked out sunlight for several months. [16a]This catastrophe would have been such a shock to the world ecosystem [16b]that it is a wonder that anything survived at all.

[17a]Most scientists today accept [17b]that an asteroid hit Earth at the end of the Cretaceous, [17c]and agree that [17d]it was at least partly responsible for the mass extinction. [18a]This conclusion was bolstered in 1992, [18b]when a crater over 100 miles across was discovered buried under the sea floor near the Yucatan Peninsula in Mexico. [19]Less certain is the role that other factors played in these events. [20]The world ecosystem was under a great deal of stress at that time because of relatively rapid changes in climate and the creation of mountain chains, both of which were altering habitats.

[21]The existence of mass extinctions illustrates an important point about the history of life on our planet. [22]Evolution is not a smooth gradual progress through time. [23]There are times when sudden changes (such as those in mass extinctions) are followed by rapid evolution, as new species develop to take the place of those that disappeared. [24]After the extinction of the dinosaurs, for example, the number of species of mammals increased dramatically. [25]Scientists continue to debate about the rate of evolution. [26]The two extremes in the debate have been the *gradualism* hypothesis, which holds that most change occurs as a result of small adaptations, and *punctuated equilibrium*, which holds that changes usually occur in short bursts, separated by long periods of stability. [27]It now appears that both these extremes, and probably any rate of evolution in between, have occurred at some time in the Earth's past.

Mass Extinctions and the Rate of Evolution

Under normal circumstances, the rate of extinction seems to be such that roughly 10 to 20% of the species at any given time will be extinct in a matter of 5 or 6 million years. The fossil record shows, however, that not all extinctions are "normal." Rare catastrophic events in the past have caused large numbers of species to become extinct suddenly. These events are called **mass extinctions.**

By "large numbers of species," we mean anywhere from 30 to 90% of the species alive at the time. By "suddenly," we mean a time too short to be resolved by standard geological techniques. The extinction may have taken place over a period of a few tens of thousands of years, or over a couple of days.

The best known of these mass extinctions is the one in which the dinosaurs perished some 65 million years ago, at the end of the Cretaceous period, which was at the end of the Mesozoic era. In that extinction, about two-thirds of all living species disappeared. In some cases, as with ocean plankton, this number may have climbed as high as 98%. But the extinction at the end of the Mesozoic was neither the largest nor the most recent mass extinction. About 250 million years ago, near the end of the Paleozoic era, about 80% of existing species disappeared in a single extinction event. A somewhat milder extinction, which wiped out 30% of existing species, appears to have taken place about 11 million years ago. In fact, geologists who study the past history of life in detail distinguish as many as 11 of these mass extinctions.

One of the most interesting explanations for how these mass extinctions could occur was put forward in 1980 by the father-and-son team of Walter Alvarez (a geologist), and Luis Alvarez (a Nobel laureate in physics). Based on evidence they accumulated, they suggested that the impact of a large asteroid killed off the dinosaurs and other life forms. Such an impact would have raised a dust cloud that would have blocked out sunlight for several months. This catastrophe would have been such a shock to the world ecosystem that it is a wonder anything survived at all.

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The existence of mass extinctions illustrates an important point about the history of life on our planet. Evolution is not a smooth, gradual progress through time. There are times when sudden changes (such as those in the mass extinctions) are followed by rapid evolution, as new species develop to take the place of those that disappeared. After the extinction of the dinosaurs, for example, the number of species of mammals increased dramatically. Scientists continue to debate about the rate of evolution. The two extremes in the debate have been the *gradualism* hypothesis, which holds that most change occurs as a result of the accumulation of small adaptations; and *punctuated equilibrium*, which holds that changes usually occur in short bursts, separated by long periods of stability. It now appears that both of these extremes, and probably any rate of evolution in between, have occurred at some time in the Earth's past.

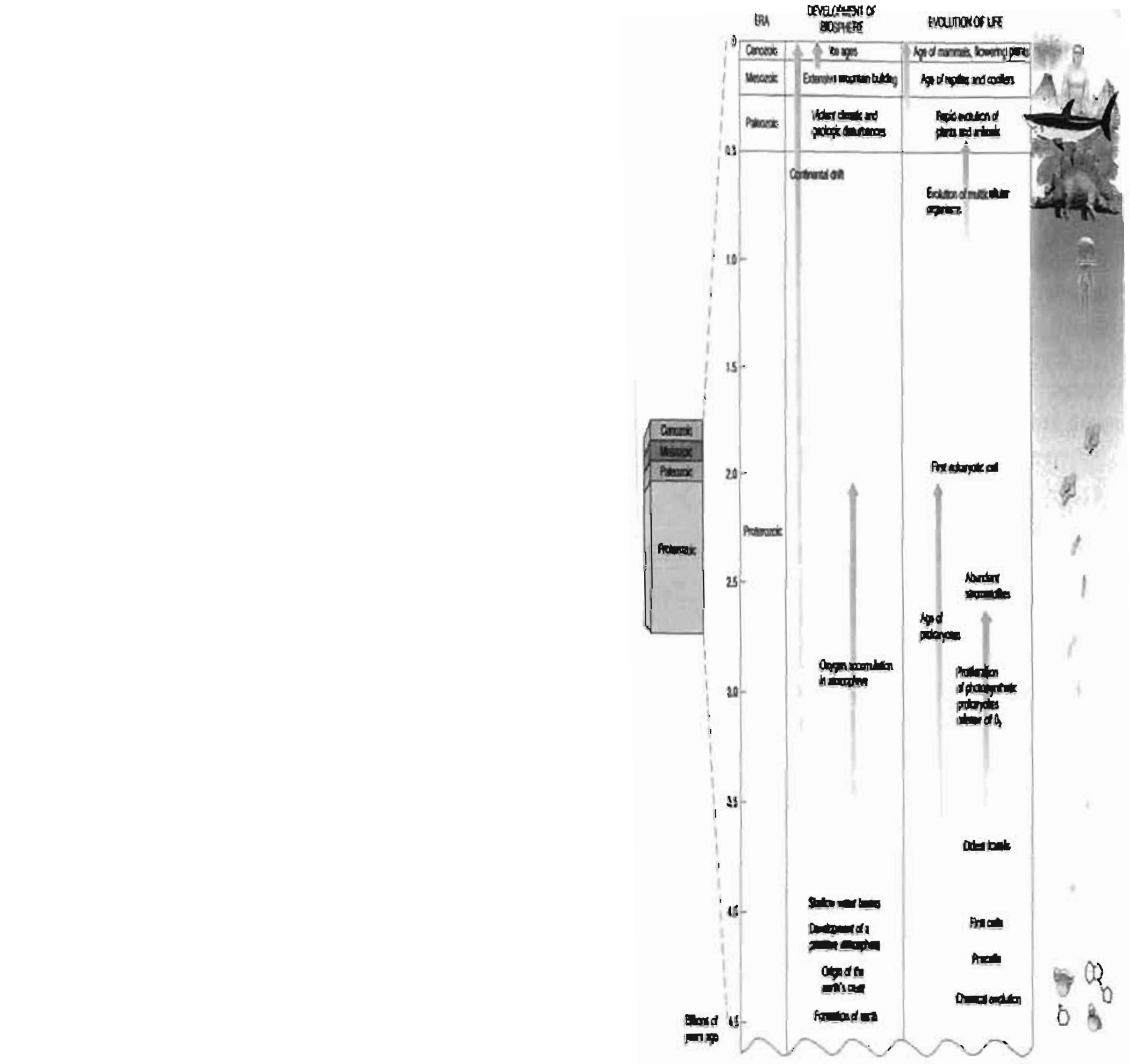

Figure 23-4
The geological time scale with representative living things illustrated.

Falling Star? (1985) *Scientific American*. 253(3):52-53.

Falling Star?

Paragraph 1

[1]The notion that extraterrestrial forces have regularly and catastrophically intruded into the history of life gained wide currency a little more than a year ago. [2a]In the scenario that has received the most attention in the scientific and popular press, a dim, distant companion star of the sun is held [2b]to send periodic showers of comets into the inner solar system, [2c]where some of the comets strike the earth, [2d]causing a mass extinction of species. [3]Called the Nemesis hypothesis after the name of the putative star, the proposal has been the subject of newspaper articles, two editorials in the New York Times and a cover story in Time magazine. [4a]A reassessment of the fossil evidence now suggests [4b]the regular extinctions said to be the handiwork of Nemesis may never have taken place.

Paragraph 2 (analysis of theme structure only)

[28]Nemesis and similar theories grew out of an earlier and more modest claim. [29a]In 1979 Luis W. Alvarez, Walter Alvarez, Frank Asaro and Helen V Michel of the University of California at Berkeley reported [29b]that a layer of clay deposited at the end of the Cretaceous period (about 65 million years ago) in Italy, Denmark and New Zealand contains anomalously high levels of iridium. [30a]Iridium is rare in the earth's crust, [30b]but is abundant in meteorites. [31]Widespread extinctions, including the demise of the dinosaurs, marked the end of the Cretaceous. [32a]The workers proposed [32b]that the extinctions and the iridium layer had a common cause: the impact of an extraterrestrial object, probably an asteroid about 10 kilometers in diameter. [33]Since then the finding that an iridium anomaly exists at many other sites around the world and that the iridium-rich clay also contains minerals apparently altered by heat and shock have bolstered the case for a Cretaceous impact.

Paragraph 3

[5]The impetus to extend the isolated event proposed by the Berkeley workers into a cycle of catastrophes came in late 1983 in the form of an analysis of stratigraphic data on fossil marine animals done by David M Raup and J John Sepkoski Jr. of the University of Chicago. [6]For each stratigraphic stage into which the fossil record of the past 250 million years is divided they determined the rate of extinction (defined as the number of families that became extinct in the stage divided by the number of families existing during the stage). [7]The rate peaked regularly at intervals of about 26 million years. [8](Statistical tests also indicated a weaker periodicity of 30 million years.) [9a]Raup and Sepkoski suggested [9b]that the periodicity reflects a recurrent event, probably of astronomical origin, in the physical environment.

Paragraph 4 (analysis of theme structure only)

[34]Astronomers and astrophysicists were quick to supply possible mechanisms. [35]In several scenarios the regular oscillation of the solar system above and below the plane of the galaxy drives the periodic mass extinctions. [36a]Michael R Rampino and Richard B Stothers of the National Aeronautics and Space Administration's Goddard Institute for Space Studies proposed, [36b]for example, that during passages through the galactic plane, which occur at intervals of about 33 million years, encounters with clouds of gas and dust

SCIENCE AND THE CITIZEN

Falling Star?

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Manicouagan Crater in Quebec, 70 kilometers wide: possible trace of a comet shower?

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Daniel P. Whitmire of the University of Southwestern Louisiana and Albert A. Jackson IV of the Computer Sciences Corporation, and simultaneously Marc Davis of Berkeley, Piet Hut of the Institute for Advanced Study in Princeton, N.J., and Richard A. Muller of Berkeley, proposed models in which the extinction periodicity reflects the orbital period of a companion star of the sun. The companion would currently lie at a distance of several light-years, but its orbit would be eccentric. Every 26 million years, at its closest approach to the sun, the star would pass through the dense inner region of the Oort cloud, a region of comets that is thought to envelop the solar system. The gravitational influence of Nemesis would precipitate a comet shower. (The star got its name when an editor at *Nature* selected it from a list of possibilities Muller and his colleagues were considering.)

Support for the notion of periodic impacts has come from the finding of a regularity in the ages of large impact craters that matches the extinction cycle; other geologic events, including reversals in the earth's magnetic field and episodes of tectonic activity, also seem to have occurred on a similar timetable. The proposed mechanisms have been criticized, however, on astronomical grounds. It appears, for example, that clouds of gas and dust are not clustered densely enough near the galactic plane to produce a sharp perturbation of the solar system's flock of comets as the sun crosses the plane. As for the Nemesis model, some workers now argue that a companion star at the great distance that is required would disturb the solar system's family of comets, [9c]setting one or more on a collision course with the earth.

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Paragraph 7 (analysis of theme structure only)

[41]Now the focus of the criticism has shifted from the models themselves to the finding that elicited them: the apparent periodicity in the fossil record. [42a]In a recent paper in *Nature* Antoni Hoffman of Columbia University contends [42b]that uncertainties in fossil dating and biases in Raup and Sepkoski's methodology cast doubt on their results.

Paragraph 8

[15a]Hoffman points out [15b]that Raup and Sepkoski pared the 3500 families in their original data down to 567 by removing families whose origin and extinction cannot be resolved to single stages and families with currently surviving species. [16]The culling of the data reduced noise and the uncertainty resulting from the fact that many recent fossils are classified as members of extant groups although they may represent morphologically similar but extinct groups. [17]But it also meant that small fluctuations in extinction rate during recent stages would be magnified by the reduced number of families under consideration. [18a]When Hoffman restored the omitted families to the data, [18b]many of the sharpest extinction peaks disappeared.

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Hoffman points out that Raup and Sepkoski pared the 3,500 families in their original data down to 567 by removing families whose origin and extinction cannot be resolved to single stages and families with currently surviving species. The culling of the data reduced noise and the uncertainty resulting from the fact that many recent fossils are classified as members of extant groups although they may represent morphologically similar but extinct groups. But it also meant that small fluctuations in extinction rate during recent stages would be magnified by the reduced number of families under consideration. When Hoffman restored the omitted families to the data, many of the sharpest extinction peaks disappeared.

The original finding of periodicity also turned out to be highly sensitive to the geologic time scale used to establish absolute dates for the stages. Equally plausible time scales for the past 250 million years or so can differ by 10 million years or more on the dates of stratigraphic boundaries. Given a time scale different from the one Raup and Sepkoski adopted, the 26-million-year periodicity weakened.

In another line of argument, presented in a paper in *Geological Magazine*, Hoffman and Joe Ghiold of Louisiana State University suggest that Raup and Sepkoski's criterion for identifying a mass extinction is biased toward periodicity. The criterion is not quantitative. Instead an episode of mass extinction is simply any local peak in extinction rate: any stage in which the rate is higher than in the preceding and following stages. To analyze the effects of that definition Hoffman and Ghiold apply it to a hypothetical model in which the rate at which families become extinct varies at random from stage to stage. For each stage the probability that the extinction rate is higher than in the stage preceding it is one-half; the likelihood of its being higher than in the following stage is also one-half. The probability that the stage represents a peak in extinction rate is therefore one in four.

Even if extinction rate varies randomly, an average of one stage in four will count as a mass extinction. In the time scale Raup and Sepkoski adopted, the geologic stages in the period they consider have average durations of 6.2 million years. Hence, Hoffman argues, Raup and Sepkoski's definition of mass extinction, together with their time scale, makes a rough periodicity of about 26 million years inevitable. There may indeed have been a periodicity in the extinction rate, but the regularity could also be an artifact. If it is, the case for Nemesis and its companion theories weakens.

Raup and Sepkoski stand by their finding. In their original work they tested their result by randomizing (shuffling) the data and analyzing it for periodicity. The 26-million-year cycle was not evident, which suggests that it is inherent in the real data and is not an artifact of the investigators' method. Since then they have done an analysis of the complete 3,500-family data set; the 26-million-year periodicity reappeared. Sepkoski has also found the regularity in extinctions analyzed at the level of the genus, a finer taxonomic division than the family. Reports of both new analyses are in press.

Hoffman's arguments do not rule out the possibility that extraterrestrial influences have shaped the history of life, even if they make it unnecessary to suppose the celestial intrusions have been regular. In applying various statistical criteria to Raup and Sepkoski's data Hoffman found that the final stage of the Cretaceous consistently qualified as a mass extinction. The unmatched disruption of the biosphere that occurred then and the coincident iridium layer continue to make a powerful case for an isolated impact's having ended the reign of the dinosaurs.

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Angier N. (1985) Did comets kill the dinosaurs? *Time*. May 6, 1985, 54-67.

[-1]Did Comets Kill The Dinosaurs?
[0]A bold new theory about mass extinction

[1a]In the Evening around the Leuschner Observatory in Lafayette, Calif., a few enterprising rattlesnakes slither out [1b]to toast themselves on the asphalt parking lot, which retains the warmth of the sun long after the air has cooled. [2]Inside a 30-in. telescope begins a laborious computer-controlled search of the heavens, covering only a tiny patch of sky during the next six hour of darkness. [3]And the following day, at the nearby University of California campus in Berkeley, Physicist Richard Muller, like a seer divining entrails, scrutinises the new batch of video recordings from Lafayette. [4]He seeks a sign of a dim star that many scientists think does not exist: Nemesis, the death star, a possible companion to the sun.

[5]Some 400 miles to the southeast, atop snow-covered Mount Palomar, Eugene Shoemaker, a geologist on leave from the U.S. Geological Survey, and his wife Carolyn, an asteroid astronomer, scurry around in the unheated dome of the 18-in. Schmidt telescope. [6a]They photograph the sky in four-minute exposures, [6b]hunting for fast-moving objects against the background of the fixed stars. [7a]So far their Palomar study has identified 25 asteroids that cross the earth's orbit, [7b]bringing the known total to 60. [8a]Asteroids like this, [8b]they think, [8a cont.] have occasionally crashed into the earth with catastrophic consequences, [8c]and they strive to calculate how frequently these inopportune meetings occur.

...

[9]These quests are all part of the controversy and ferment that have been bubbling through the scientific community since the rise of a spectacular new theory that attempts to explain the mass extinctions - most notably the one in which the dinosaurs perished - that have punctuated the history of life on this planet. [10a]Every 26 million years or so, [10b]the theory holds, [10a cont.] a rain of comets that lasts hundreds or thousands of centuries bombards the earth. [11a]The impact of some of the larger comets spews enough debris into the atmosphere [11b]to block the sun for months. [12a]As the skies darken, [12b]temperatures on the ground plummet [12c]and the majority of existing plant and animal species perish.

[13]Galvanised by this radical proposal, researchers are hunting for an agent that could explain the apparent clockwork regularity of the celestial barrages. [14a]Some suggest [14b]that a companion star to the sun periodically comes close enough [14c]to nudge comets gravitationally out of their natural habitat- a cloud of comets that circles the sun far beyond the orbit of Pluto - [14d]sending them hurtling towards earth. [15a]Others assign that role to Planet X, [15b]while some insist [15c]that the slow, bobbing ride of the sun and its planets around the Milky Way galaxy is responsible. [16a]Whatever the details, [16b]declares Palaeontologist J John Sepkoski Jr. of the University of Chicago, [16c]the evidence for the periodic mass extinctions "very strongly implicates an extraterrestrial mechanism."

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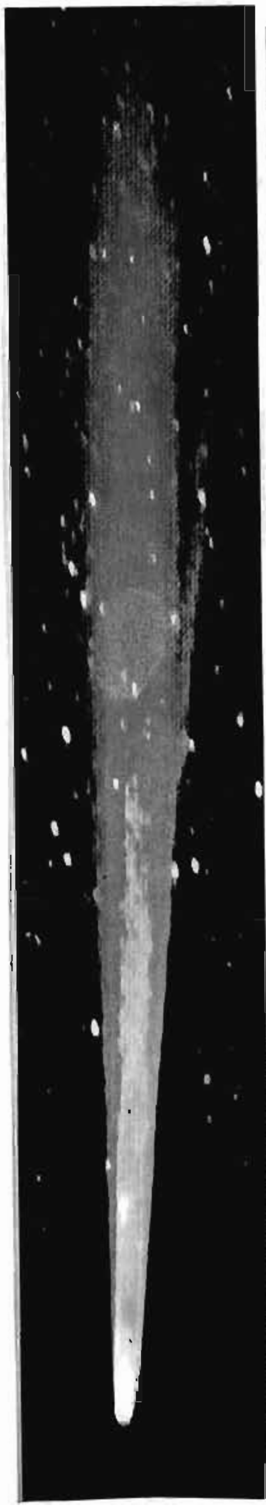

Halley's comet blossoms in false color in this computer-enhanced version of a 1910 photo

Science

COVER STORY

Did Comets Kill The Dinosaurs?

A bold new theory about mass extinctions

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As the Shoemakers chart the asteroids' travels, astronomers at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., hunt for another elusive creature of the night: the legendary tenth planet, or Planet X. They comb through the tangled statistics and images transmitted in 1983 from the now defunct orbiting Infrared Astronomical Satellite (I.R.A.S.), struggling to find a single pinpoint source of radiation that over a six-month period has shifted in a particular pattern among the fixed stars, as only a nearby planet can do. Says Daniel Whitmire, a University of Southwestern Louisiana astrophysicist who is involved in the search: "There's a chance it's already been recorded and is awaiting discovery right now."

These quests are all part of the controversy and ferment that have been bubbling through the scientific community since the rise of a spectacular new theory that attempts to explain the mass extinctions—most notably the one in which the dinosaurs perished—that have punctuated the history of life on this planet. Every 26 million years or so, the theory holds, a rain of comets that lasts hundreds or thousands of centuries bombards the earth. The impact of some of the larger comets spews enough debris into the atmosphere to block the sun for months. As the skies darken, temperatures on the ground plummet and the majority of existing plant and animal species perish.

Galvanized by this radical proposal, researchers are hunting for an agent that could explain the apparent clockwork regularity of the celestial barrages. Some suggest that a companion star to the sun periodically comes close enough to nudge comets gravitationally out of their natural habitat—a cloud of comets that circles the sun far beyond the orbit of Pluto—sending them hurtling toward earth. Others assign that role to Planet X, while some insist that the slow, bobbing ride of the sun and its planets around the Milky Way galaxy is responsible. Whatever the details, declares Paleontologist J. John Sepkoski Jr. of the University of Chicago, the evidence for periodic mass extinctions "very strongly implicates an extraterrestrial mechanism."

If the theory is correct, the next catastrophe will not occur for at least 13 million years. But the effect of the new concept on science and scientists has been much more immediate. One measure is the ferocity of debate it has generated in the past few months among eminent researchers, at conferences and in the letters-to-the-editor columns of major newspapers and staid journals alike. Supporters of the Milky Way proposal dismiss the Nemesis notion as "unlikely" and "ad hoc," and death star advocates are scornful of the galactic concept. Many consider all the newfangled extraterrestrial scenarios to be half-baked takeoffs of H.G. Wells. Says an indignant Dewey McLean, a paleontologist at Virginia Polytechnic Institute: "It's science gone absolutely bonkers."

The controversy has engulfed not only astronomers, geologists, paleontologists and astrophysicists but even evolutionary biologists. If the cyclic theory is true, the biologists argue, many assumptions about the course of evolution on earth—and even the likelihood of finding complex life forms on other planets—will be overturned. Says Whitmire: "Just the possibility that life here has been controlled by an astronomical event is very far reaching."

In one sense, the current fights over extinction theories are merely the latest variation of a venerable tradition that dates back to the early 19th century, when a growing corps of paleontologists and geologists had determined that the world is not the static Eden-like meadow of legend. At least intermittently, they concluded, it is an unstable, dangerous place, where vast numbers of species, like the giant mastodons, mysteriously disappear. Eventually, after analyzing the bones long thought to be the remains of dragons, they pieced together the almost more fantastical story of the dinosaurs and their inexplicable demise. They zealously dug up fossils of mysterious plants, insects, small animals and marine organisms, compared them with living ones, and pondered their disappearance from the earth. Had it been sudden and catastrophic, or gradual?

Fossil bones in Alberta's Dinosaur Park

Fanciful tales and remains of dragons.

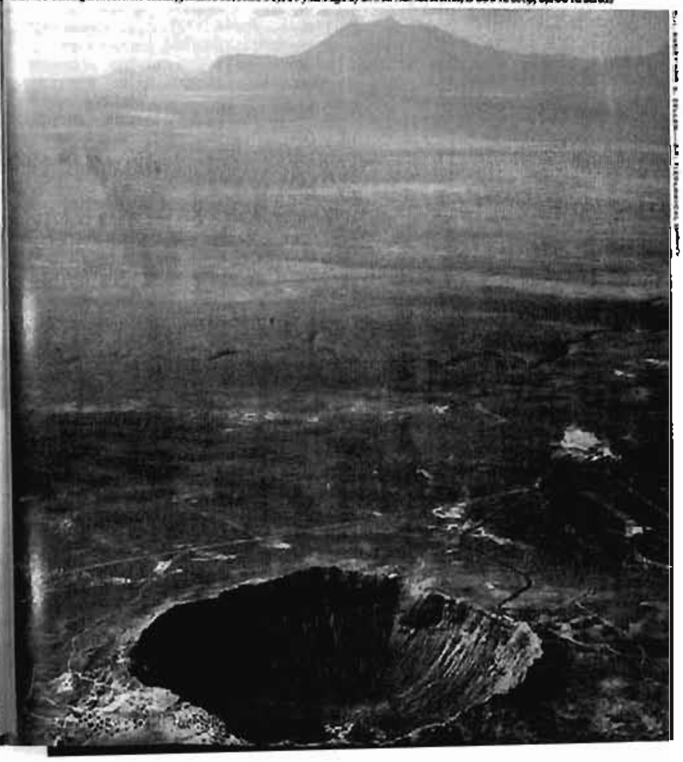
Some Victorian scientists viewed the discoveries as evidence of a primordial flood, possibly Noah's. A few linked extinctions to the fury of volcanoes; their conjecture was based on the extraordinary explosion in 1883 of Krakatoa, a volcano between Java and Sumatra, which darkened the skies and triggered a giant tidal wave that drowned 36,000 people.

In the end, however, most of the scholars responded to the lure of Darwin, insisting that creatures die out because they are no longer fit to survive and must give way to the supremacy of the new. That argument seemed to apply particularly well to the dinosaurs, which were denigrated as being too big, too slow, too pea-brained and too cold-blooded for their own good.

As geology became more precise, scientists determined from the fossil record that at least five great dyings—and numerous smaller events—have occurred in the past 600 million years. Among the more significant: the Cambrian disasters some 500 million years ago, when many species of segmented creatures called trilobites disappeared from the seas they once dominated; the biggest of the extinctions, the Permian cataclysm of 248 million years ago, when up to 90% of all marine species died; and the late-Cretaceous event 65 million years ago, which saw the destruction of the dinosaurs and many other groups of species, including the microscopic organisms responsible for creation of the white cliffs of Dover. The effects on evolution were profound. "In wiping the slate clean," says Muller, "these catastrophes opened up ecological niches and prevented stagnation."

Yet for all the evidence of destruction, scientists could not figure out where the eraser was hidden. Geologists naturally

Arizona's Barringer Meteorite Crater, punched out some 50,000 years ago by an iron-rich meteorite, is 550 ft. deep, 3,900 ft. across



[17]The revolution began with an unassuming element known as iridium, a rare and hard silvery-white metal related to platinum and gold. [18a]In the spring of 1977, Geologist Walter Alvarez of the university of California, Berkeley, was carefully chiseling through the rocks outside Gubbio, a medieval Italian town, halfway between Florence and Rome, [18b]seeking clues to continental drift. [19a]Gubbio has long been an appealing site to geologists and palaeontologists [19b]because its rocks provide a complete geological record of the critical boundary line between the end of the Cretaceous period, when the dinosaurs disappeared, and the Tertiary period, which followed it.

[20a]As he chiseled, [20b]Alvarez was struck by a configuration of sediment layers, which resembled a sandwich in stone. [21]The bottom or older layer consisted of Cretaceous limestone, which was full of tiny fossils. [22]On top was a second slice of limestone, from the Tertiary period, almost devoid of fossils. [23]Like other samples of rock from that era, it showed that the creatures alive during the late Cretaceous period had, by geological time scales, suddenly disappeared. [24]In between the limestone layers was a dull red layer of clay about half an inch thick, first discovered by an Italian palaeontologist around 1960.

[25]Alvarez, his curiosity aroused, shipped samples of the sediment back to his father Luis, a nobel-prizewinning physicist at the University of California, who had the clay analysed. [26]To everybody's surprise, it turned out to be 30 times as rich in iridium as normal rocks. [27]The Berkeley team knew of only a few places where such high concentrations of the rare element might occur: in the earth's core, perhaps 2000 miles belowground; in extraterrestrial objects like asteroids (or their fragments, meteors) and comets; or in the cosmic dust drifting to earth from a nearby supernova (exploding star). [28a]The core material seemed too deep to come to the surface, [28b]and further analysis ruled out a supernova as the source, [28c]so father and son concluded [28d]that the iridium had been left by a giant asteroid hitting the earth at the end of the Cretaceous period.

[29]The Alvarezes did not stop there. [30]Basing their calculations on the atmospheric consequences of the explosion of Krakatoa, they roughly estimated how much dust the impact of the asteroid would have thrown into the atmosphere, how long sunlight would have been blocked from the earth's surface, and what kinds of life would have been the most gravely affected by the climatic changes. [31a]They decided [31b]that plants, totally dependant on the sun for photosynthesis, and a variety of marine organisms would have died first, followed by the land animals highest on the food-chain, the dinosaurs. [32]Eventually the iridium-enriched debris, circulating around the world in the atmosphere, would have settled like a sprinkling of black snow over most of the globe. [33](It was the Alvarezes' theory that helped to shape the now familiar concept of nuclear winter.)

[34a]Journeying to Denmark, another site where the Cretaceous geological record is complete, Walter Alvarez gathered corroborating samples of iridium [34b]and received still more from colleagues working on a third site on the other side of the world, in New Zealand. [35]The evidence seemed overwhelming. [36a]In 1980 the Alvarez team finally published its results in the journal, *Science*, [36b]and stirred up some scientific debris of its own. [37a]Says Palaeontologist Leo Hickey, director of the Museum of Natural History at Yale: [37b]"My first thought was this is one of Walter's practical jokes."

A ROCK RECORD

Fossil evidence suggests that a mass extinction occurs every 26 million years or so, wiping out, among others, some families of the creatures shown below.

Walter and Luis Alvarez peering through a transparent star dome in Berkeley, Calif.

looked to the earth for explanations, citing changes in climate or sea level. By the mid-1960s, scientists had concluded that the planet's tectonic plates are continually on the move, bumping and grinding against each other to produce earthquakes and mountains, or separating to tug apart land masses and rearrange the oceans. When sea levels change, they reasoned, animal habitats in low-lying areas may be destroyed, or the climate farther inland may grow more extreme.

What is more, the restless tectonic plates spawn volcanic eruptions, which spew carbon dioxide into the air. The increase in atmospheric carbon dioxide results in a greenhouse effect, which traps the sun's energy, causing temperatures on land and in the sea to rise markedly. Conversely, crustal movement may allow frigid ocean currents from the poles to invade tropical waters, leading to a worldwide drop in temperatures. Those species that cannot adapt to the earth's erratic behavior simply succumb. To many paleontologists, as well as geologists, it seemed to make sense.

Serious questions remained, however. Why, for example, were extinctions so selective, devastating some species while leaving others virtually unscathed? Try as they might, scientists could not devise a single elegant theory to tie the loose ends together. They were about to get what they asked for, but like the British author W.W. Jacob's infamous monkey's paw (which granted wishes—at a price) it would not be an unsullied blessing.

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Sepkoski and Raup pondering cycles

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existence might be tested. He knew that if comets cyclically pelted the planet, they must have left behind craters in chronologically distinct batches. Water, wind and continental drift have eroded most of the earth's impact craters, but 100 of the largest survive in some form and have been roughly dated. Muller and Walter Alvarez examined the data on 13 of the best-dated craters spanning a period of 250 million years and, sure enough, the cratering seemed to occur in peaks of 28.4 million years (although the later inclusion of data from other craters made the pattern seem less conclusive).

The results of the crater analysis were published in the British journal *Nature*, right beside the Nemesis report. Coincidentally, that same issue contained yet another paper on the death star. It was from Whitmire, who had independently conceived of a companion to the sun.

Reviews for the Nemesis debut were what might be called mixed. Critics charged that so gigantic an orbit had never been recorded for two companion stars, and with good reason. If the sun and its presumed partner were actually three light-years (18 trillion miles) apart, they said, the gravitational attraction between them would be so feeble that a passing star or dust cloud would have bumped Nemesis out of orbit long ago, certainly before it could come back through the Oort cloud a dozen times. Says Shoemaker, who has been something of an impartial judge in the periodicity controversy: "I give this idea less than a 1% chance of being correct."

The warrior star, however, has captured the imagination of many others. Says Tom Gehrels, an astronomer with the University of Arizona: "When I heard the theory, I knew in my heart it was right." Indeed, Gehrels immediately hopped on a westbound plane to try to persuade Muller to let him help search for the companion. But Muller's own telescopic dissection of 5,000 stars in the Northern Hemisphere that are candidates for being Nemesis was already under way, and there was no need for Gehrels' help. So far, Muller has photographed nearly all the target stars once and is preparing to shoot them again in an attempt to detect some telltale movement.

Offers of assistance have come from other quarters as well. Jordin Kare, a physicist with Lawrence Berkeley Laboratory, has suggested that a 24-in. Schmidt telescope in Australia be used with a computer scanning system called the Star Cruncher to survey the Southern Hemisphere skies. If these approaches turn up a blank, Kare and Muller will launch a Star Cruncher search in the north. And at JPL, Astrophysicist Thomas Chester, chief of the I.R.A.S. data team, is sifting through recorded I.R.A.S. transmissions looking for Nemesis and other unusual objects. Although I.R.A.S. operated for only ten months in 1983 before dying, it managed to chug out data on

William Clemens and a cast skull of a victim of extinction: Tyrannosaurus

Why should the mammals have survived any Cretaceous catastrophe?

250,000 cosmic objects, which scientists have just begun to analyze. Chester is hunting for cool stars that may have suspiciously shifted. To date he has identified 5,000 likely objects and narrowed the list to 15, which he plans to photograph half a year apart to check further if they are candidates for the star role of Nemesis. Says Muller: "I figure all these searches could take about two years."

Early this year, another scientist joined the Nemesis hunting party. Armand Delsemme, a Belgian-born astrophysicist at the University of Toledo in Ohio, announced that he had just about zeroed in on the best place for Muller or Chester to look for the death star. He has plotted the paths of 126 comets and discovered to his great surprise that they journey around the sun in oddly skewed orbits. Some very powerful object must be out there gravitationally directing the flow of traffic, he says, and that object could be Nemesis.

Although Louisiana Astrophysicist Whitmire does not dismiss the death star theory, he thinks that his Planet X theory of periodic comet showers has greater potential. For one thing, a still undiscovered planet has a distinct advantage over Nemesis as a promising candidate because astronomers have been predicting its existence since the late 19th century, first as the ninth planet and then as the tenth. Reason: its existence and gravitational pull might explain discrepancies in the movements of Neptune and Uranus. Even the discovery of Pluto in 1930 did not fulfill the gravitational force needed to justify Uranus' meanderings, and some astronomers have long thought that a tenth planet is somewhere out there. Astronomer Robert Harrington of the U.S. Naval Observatory has gone so far as to paint a description of the suspect, and it is no pedestrian planet. It is three to five times the mass of the earth, is gaseous like Jupiter, has an orbit that is elliptical rather than circular and inclines to the plane of the solar system at an angle of perhaps 30° or more. Its year (the time it takes to orbit the sun once) is 800 to 1,000 earth years long. To have been influential in shaping the current orbit of Uranus, he thinks, it made its closest approach to that planet in the 1700s.

In devising their Planet X model, Whitmire and fellow Louisiana Astrophysicist John Matese took an entirely different tack, determining the nature and orbit of a planet that would loose rains of comets at the necessary intervals. The result of their calculations: a planet with an orbital plane that slowly rotates around the sun, completing its cycle once every 56 million years. Twice during that cycle, every 28 million years, Planet X's orbit carries it through a disk of comets lying just beyond Neptune, dislodging many of them.

To meet all the other requirements imposed on it by the Louisiana scientists, Planet X would have an orbit that is elongated and highly inclined and a mass one to five times that of the earth. In other words, their Planet X is remarkably similar to the one that could account for the irregularities in the orbit of Uranus. The beauty of the theory, in Whitmire's view, is that it relies on a planet originally proposed for reasons that have nothing to do with mass extinctions. Still, he admits, the proof of the pudding "is going to come in the observing."

Most scientists are waiting for that pudding to be served before they commit themselves to the idea of periodicity, let alone a particular model. Says Cornell Astronomer Carl Sagan: "None of the explanations is anything like fully satisfying." Yet all but a few diehards acknowledge the brilliance of the Alvarez work. They believe the iridium layer and subsequent discoveries indicate that impacts of extraterrestrial objects may have played a

[60a]Other scientists, drawn into the fray by the Alvarez conjecture, have since suggested [60b]that a large comet might have similar consequences. [61a]Los Alamos Weapons Experts Stirling Colgate and Albert Petschek computed [61b]that a comet six miles in diameter hitting the earth would have an effect 100,000 to 1 million times as great as a nuclear explosion, [61c]and would blow a 100-sq-mi hole in the atmosphere.

[62a]Several researchers rushed forth to deny any extraterrestrial origins for the iridium, [62b]attributing it first to a gradual process of sedimentation that concentrated the metal. [63]Later an old favorite was proposed – volcanic eruptions, which might have forced iridium from the mantle to the surface. [64]The most recent naysayers are Dartmouth Geologists Charles Officer and Charles Drake, who reported in *Science* on their studies of two other telltale elements in the boundary clay between the Cretaceous and Tertiary periods. [65a]They found [65b]that the levels of arsenic and antimony correspond to decidedly terrestrial, not cosmic, concentrations.

[38]One of the Alvarezes' staunchest critics has been William Clemens, a palaeontologist at the University of California, Berkeley. [39a]After systematically sampling parts of the eastern Montana area, [39b]he declared [39c]that the layer of iridium and the bones of the last surviving dinosaur were too far apart [39d]to share any meaningful connection. [40a]Besides, [40b]he asked, [40a cont.] why should the mammals have survived any Cretaceous catastrophe? [41a]Says he: [41b]"If you're going to have a nuclear winter killing off the dinosaurs, [41c]why didn't it kill off everything else?"

[42]Nonetheless, the evidence in favour of an impact was rapidly accumulating. [43]Other geologists uncovered similar iridium deposits just above Cretaceous rock beneath the floor of the Atlantic Ocean and under the Raton basin in northeastern New Mexico. [44]Additional analysis showed that the samples contained ratios of gold and platinum nearly identical to those found in meteorites. [45]Furthermore, other sediment layers containing abnormally high amounts of iridium were discovered under both the Carribean Sea and the Gulf of Mexico; [46]these layers were deposited around the time of a smaller mass extinction that occurred more than 30 million years ago, at the end of the Eocene epoch. [47]In addition to the iridium anomaly, the sediments harbored microscopic balls of glass called microtectites, which form in rock when something hits it with great force - further evidence of a major collision. [48]Yet investigators continued to regard the findings from the two time periods as being no more related than, say, separate automobile accidents in Des Moines and Miami. [49a]Explains Walter Alvarez: [49b]"It seemed to everybody involved that extinctions and impact should be random in time."

[50a]That impression began to change in 1983, [50b]when Sepkoski and a colleague, Palaeontologist David Raup of the University of Chicago, presented a paper in Flagstaff, Ariz., at a symposium on mass extinctions. [51]The pair had examined data on marine organisms that had become extinct over the past 250 million years, a list of about 3,500 families that included an estimated quarter of a million species.

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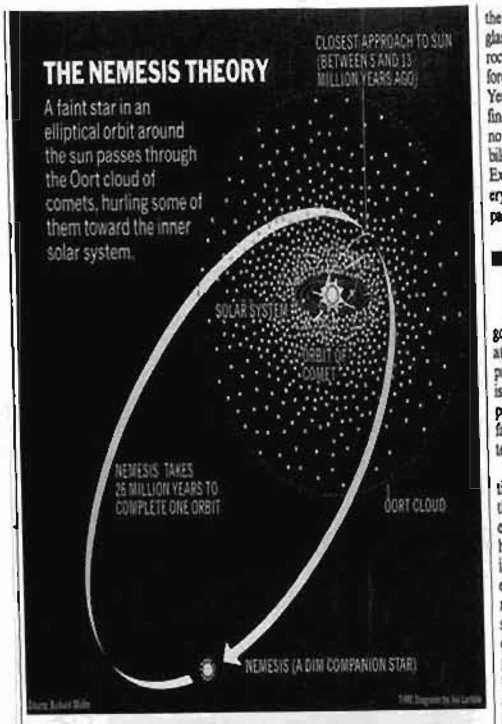

Richard Muller scanning the night sky at the Leuschner Observatory. Is Nemesis there?

Some very powerful object must be directing the flow of traffic.

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The implications were compelling. No earthly phenomena, no Vesuvian eruptions, no swelling seas, no ice ages could explain the regularity. Eyes turned heavenward. As Raup and Sepkoski declared in their paper on the subject, "We favor extraterrestrial causes." It did not take long for skygazers, ever an imaginative group, to begin coming up with candidates. Because researchers could not invent a convincing celestial event that would periodically disturb the nearby belt of asteroids that circle the sun between the orbits of Mars and Jupiter, attention turned to swifter and icier astronomical travelers, the comets.

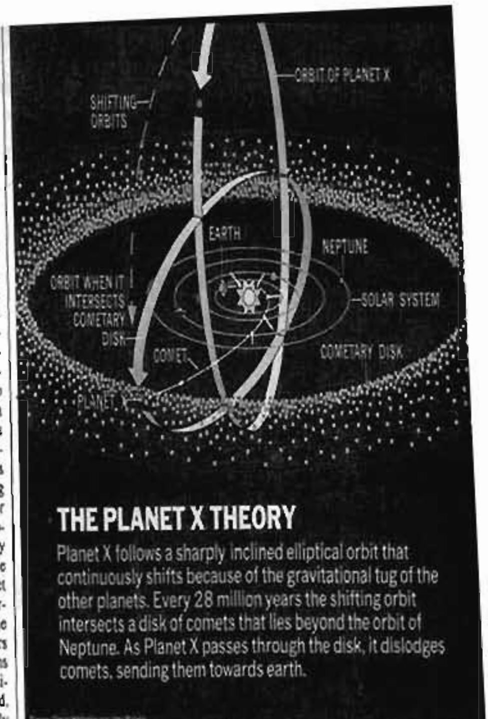
Among the first cyclic mechanisms considered was one already familiar to astronomers: the sun's undulating route around the crowded Milky Way galaxy, an island of some 100 billion stars. The Milky Way is shaped something like a sunny-side-up egg, 100,000 light-years in diameter, with a bulge (the yolk) in the middle and three flat, dusty arms (the egg white) forming a circle around it. Like all its fellow stars, the sun revolves around the galactic center, taking about 250 million years to complete a round trip. As it moves, it bobs up and down through the central plane of the galaxy, where most of the stars and dust clouds are concentrated. Says Michael Rampino, a geologist with the Goddard Institute for Space Studies in New York City: "It's like a horse on a merry-go-round." Significantly, the sun and its accompanying planets hit the dustiest sections once every 33 million years or so, a figure that does not quite jibe with the apparent extinction cycle of 26 million years but is at least within the margins of astronomical and geological error.

Sniffing a connection, Rampino and a Goddard colleague, Astrophysicist Richard Stothers, among others, proposed an ingenious way that the oscillating journey might trigger bombardments on earth. Whenever the sun passes through the Milky Way plane, they suggested, the swirls of dust it encounters would gravitationally disrupt the Oort cloud, a vast bubble of comets that scientists believe surrounds the solar system at a distance of up to 10 trillion miles from the sun. Like a lazy fruit picker shaking plums from a tree, the dust would send showers of comets falling toward the sun. Some comets would collide with the planets, including the earth. Almost immediately, other scientists began tearing the Rampino-Stothers model apart. First of all, they said, the sun is pretty close to the middle of the galactic plane right now, and yet there has been no major extinction occurrence for millions of years (the last one apparently took place 11 million years ago, wiping out some marine protozoans and mollusks). More damning still, Physicist Patrick Thaddeus, also of Goddard, pointed out that dust clouds are so widely distributed that the Oort cloud should be encountering them practically all the time, not just once every 33 million years; some of the numbers his colleagues used in their calculations, he says flatly, are "just the wrong numbers."

Among the various astronomers who considered and promptly rejected the galactic carrousel notion was California's Muller, a scientist obsessed by periodicity. If a familiar cosmic mechanism could not account for the cyclic nature of extinctions, he decided, something completely different would have to do. During Christmas break in 1983, Muller and fellow Astronomers Marc Davis of Berkeley and Piet Hut of the Institute for Advanced Study in Princeton were brainstorming about stars and periodicity, when Muller noted that more than half the stars in the galaxy are thought to be binaries (pairs of stars that orbit a common center of gravity). Suppose the sun has a companion, he mused, and that companion was somehow disrupting the solar system's asteroid belt. Trouble was, he conceded, he could not come up with a convincing orbit for the companion. Suddenly the Dutch-born Hut interrupted him with an alternative suggestion: Why not make the companion star travel through the thickest part of the comet-filled Oort cloud, rather than the asteroid belt? Muller immediately saw that the problems he had had with asteroids disappeared when he substituted comets as the culprits. As he recalls, "We wrote the first draft of our paper that day."

The three realized that the sun's counterpart, if it existed, would have to be like no other companion star ever identified: it would travel in an enormous elliptical orbit three light-years across that would periodically take it farther from the sun than the distance between any known binary stars. Because it has not been identified in the four centuries since astronomers began using telescopes, it must be very small and dim, perhaps a red dwarf with one-third the mass and only one one-thousandth the brilliance of the sun. When it passed through the Oort cloud, it would dislodg billion or more comets. Muller, searchi for an appropriate name for the leth companion, considered several. But t one that stuck was Nemesis, the Gre goddess who punishes the proud.

Before publishing their report, Mul decided to get a second opinion from t fathers of the impact theory, Luis a Walter Alvarez. Neither conferred benediction on the hypothetical star, Walter recommended one way that



John Matese and Daniel Whitmire plotting the probable orbit of the mysterious Planet X

To loose the rain of comets and justify the meanderings of Uranus.

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Matthews, Robert (1999) Why dinosaurs won't go away. *Mail and Guardian*. November 5 to 11, 1999, 23.

[1a]Discovering the fate of dinosaurs is the hot topic in palaeontology right now – [1b]at least, it is among those who don't see it as another source of trivialisation of their subject. [2]The fact that no single, sure-fire way has been found to get rid of dinosaurs is perhaps the most telling tribute science has yet paid them.

[3]Hardly a week goes by without some new theory for zapping the dinosaurs hitting the headlines. [4]A few years back, it was death by volcanic eruption. [5a]By throwing huge amounts of dust into the atmosphere, these could have blotted out the sun's light, [5b]killing vegetation [5c]and thus trashing the food chain. [6]Since then we have had death by genetic changes, death by continental break-up, and, most famously, death by meteor impact. [7]An impact between a very big rock and a hard place at something like 96 000kph, unleashing the violence of 10-million hydrogen bombs. [8a]That ought to have sorted the big oafs out, [8b]you would think. [9]But no.

[10a]Most right-thinking palaeontologists today do not believe [(10b)]that even this monumental impact was enough, by itself, [10c]to knock T-rex off his perch. [11]Instead, they subscribe to the theory of death by all of the above: a multiple-whammy of volcanic eruptions, genetic and geological changes - with a meteor-impact chaser.

[12]Academics would naturally prefer that the explanation of the extinction of the dinosaurs were simple. [13]Indeed, there are those who insist there is only one explanation (namely their own). [14]But there is one last, humungous fact standing in the way of all one shot kills all theories.

[15]Dinosaurs were the dominant life form on this planet for 160-million years. [16]During that time - 40 times longer than anything approaching humans have been around - dinosaurs had seen it all. [17]Climatic upheaval, shifting continents, volcanic eruptions meteor impacts? [18a]Been there, [18b]survived that. [19]Only the incredibly rare event of several global catastrophes striking all at the same time could finally do the dinosaurs in.

MAIL & GUARDIAN
November 5 to 11 1999

Why dinosaurs won't go away

Dinosaurs were vicious, stupid and doomed. Why then, asks **Robert Matthews** *do the terrible lizards still fascinate us more than 65-million years after they were wiped from Earth?*

Loud, gormless and likely to bite your head off: dinosaurs were just made for a successful light entertainment show. And thus it has proved, with audiences of 13-million plus watching the BBC's *Walking with Dinosaurs* series, now showing on South African television.

The wonder is that it has taken the BBC so long to realise the audience-boosting abilities of dinosaurs. For if there is one sure-fire way of getting millions of people to drop whatever they are doing and come running, it is by bringing T-rex and his friends up close and personal.

Just ask Steven Spielberg: his 1993 spectacular *Jurassic Park* made him more than $350-million. And he was only doing what that Victorian arch-popularist, Sir Arthur Conan Doyle, had done with the original dinosaur blockbuster, *The Lost World*. It is a fascination that transcends cultures. The 1954 film *Godzilla: King of the Monsters* was a smash in both Japan and the United States — and spawned no fewer than 14 sequels.

The British are particularly in thrall to the beasts: *Jurassic Park* made more than £47-million over there. But then the British were also the first to learn the awful truth that still lies at the centre of all dinomania: that despite what we might think, humans are not The Greatest Creatures That Have Ever Lived.

The first hints of this humiliating little fact surfaced about 300 years ago. Someone in Oxfordshire dug up a huge bony object which ended up in the possession of a Professor Robert Plot of Oxford University.

The specimen bore some similarities to the leg bone of a cow — but judging by its size, a cow whose udder could only be reached via a stepladder. Unable to come to any reasonable conclusion, Professor Plot came to an unreasonable one: the bone had come from a long-dead human giant. Which is two-thirds correct — and the bit he got wrong is telling.

For the assumption that the bone must be human is a straight-line deduction from the assumption that humans have been, and always have been, the greatest.

Not until the 19th century, when entire skeletons had been unearthed from many sites across Europe, did the truth become inescapable.

Some time in the distant past, colossal reptiles had rampaged across Britain. By 1842 these monsters had been given that most famous of taxonomic monikers: dinosaur, from the Greek for terrible lizard.

The revelation of their existence came with a rider: they don't exist anymore. Like Percy Shelley's Ozymandias, dinosaurs were apparently once-powerful and unchallenged rulers of the world — and now they are gone.

Evolutionary biologist Stephen Jay Gould has argued that the fact that they are no longer around lies at the heart of their appeal. Attempting to explain our fascination, he writes: "I know of no better response than the epitome proposed by a psychologist colleague: big, fierce, extinct — in other words, alluringly scary, but sufficiently safe."

In truth, of course, far more attention has been devoted to unravelling the science of dinosaurs than to understanding their place in our consciousness.

As the American scholar WJT Mitchell put it: "What we do not yet understand is the cultural function of the dinosaur, its strange, chameleon-like status as a scientific wonder, a children's toy, a corporate logo, a voracious monster, a civic monument, and a synonym for obsolescence." It's the last of these roles that seems to represent a paradox — why should dinosaurs remain so popular when they are frequently used as a symbol of failure to adapt?

The lost world: The BBC's series, Walking with Dinosaurs, brings T-rex and his friends up close and personal

"To be called a dinosaur in a rapidly changing, competitive market economy is hardly a prescription for commercial attractiveness," notes Mitchell.

If the appeal of dinosaurs is tied up with the salutary image of raw power suddenly extinguished, then the makers of *Walking with Dinosaurs* have hit the nail on the head, sparing no expense to expose us to both the triumph and tragedy of the terrible lizards. They have twigged that it does not matter how many times you hear about dinosaurs, there is still something even more awful about them you haven't heard before.

An example is the episode about marine dinosaurs. When it started, no doubt most of the millions tuning in felt safe in the knowledge that T-rex was the biggest carnivore ever seen on Earth. Within the first 60 seconds, they had been spectacularly disabused of that notion. They saw the demise of some hapless little beachcombing dinosaur in the 270cm jaws of liopleurodon, the crocodile from hell. The beast downed its victim like a bit of sushi before vanishing back beneath the waves.

Weighing more than 100 tons, liopleurodon really is the largest carnivore the world has ever seen — and makes poor T-rex look like the "before" picture in a body-building advert.

You can almost hear the sound of moulding machines cranking into action in China right now, trying to catch the Christmas demand for plastic liopleurodons.

Inevitably, there are those who think that the makers of the series have gone over the top with all the flashy animatronics, computer graphics and exotic locations. Hardly had the show begun in Britain than academics were starting to roll their eyes at some of the florid Attenborough-ese in Kenneth Branagh's voiceover.

It is a criticism that series producer Tim Haines sees as typical of academics who can't see the wood for the members of the genus Larix.

Yes, of course there is some guesswork in the imagery on screen, admits Haines. But scientists do not — and perhaps never will — know everything about dinosaurs. So should we all sit quietly until the Gradgrinds of academe decide when we should be permitted to be thrilled?

Haines can call on impressive academic support for his contention. In the middle of the last century the eminent Victorian naturalist Richard Owen, the man who coined the word dinosaur, had a shot at recreating the monsters of which only bones had been found. His life-size concrete mock-ups were soon shown to be scientifically inaccurate — but they created a sensation which reverberates to this day. Shown at the Great Exhibition of 1851, they drew huge crowds, and even made the pages of the *Illustrated London News*, which reported how a dinner party had been held in the hollow body of an iguanodon.

Professional palaeontologists may wince at such stunts, but the fact is that it is the vulgarian models of fighting dinosaurs that bring in the dosh at the museums where they work — not the cabinets of bone shards.

But there is another reason for constantly playing up the monumental size and power of dinosaurs. At a time when bouffant-haired men with braces call themselves masters of the universe, it seems important to know what the real thing looked like — and to wonder what did for them.

Discovering the fate of dinosaurs is the hot topic in palaeontology right now — at least, it is among those who don't see it as another source of trivialisation of their subject. The fact that no single, sure-fire way has yet been found to get rid of dinosaurs is perhaps the most telling tribute science has yet paid them.

Hardly a week goes by without some new theory for zapping the dinosaurs hitting the headlines. A few years back, a favourite theory was death by volcanic eruption. By throwing huge amounts of dust into the atmosphere, these could have blotted out the sun's light, killing vegetation and thus trashing the food chain. Since then we have had death by genetic changes, death by continental break-up, and, most famously, death by meteor impact. An impact between a very big rock and a hard place at something like 96 000kph, unleashing the violence of 10-million hydrogen bombs. That ought to have sorted the big oafs out, you would think. But no.

Most right-thinking palaeontologists today do not believe that even this monumental impact was enough, by itself, to knock T-rex off his perch. Instead, they subscribe to the theory of death by all of the above: a multiple-whammy of volcanic eruptions, genetic and geological changes — with a meteor-impact chaser.

Academics would naturally prefer that the explanation of the extinction of the dinosaurs were simple. Indeed, there are still those who insist there is only one explanation (namely, their own). But there is one last, humungous fact standing in the way of all one-shot-kills-all theories.

Dinosaurs were the dominant life form on this planet for 160-million years. During that time — 40 times longer than anything approaching humans have been around — dinosaurs had seen it all. Climatic upheaval, shifting continents, volcanic eruptions, meteor impacts? Been there, survived that. Only the incredibly rare event of several global catastrophes striking all at the same time could finally do the dinosaurs in.

No doubt the *Walking with Dinosaurs* team has got some spectacular special effects lined up to show that the fate of terrible lizards was suitably terrible. No doubt it will make some academic seethe. But for the rest of us, it will allow us to savour the final, thrilling frisson in our relationship with these long-dead monsters: their dreadful testimony that, in the end, we're all dead.

Catch Walking with Dinosaurs on SABC3 on Sundays at 6.30pm

Benton, Mike (1990) *All About Dinosaurs* Kingfisher: London, 42-43.

[1]What happened?

[2]Sixty-six million years ago, the dinosaurs died out. [3]We are not sure why this happened.

[4a]At one time, scientists thought that [4b]the early mammals ate the dinosaurs' eggs. [5a]But dinosaurs laid a lot of eggs [5b]and their eggs were big. [6]So how could those little mammals have eaten all of the eggs?

[7]Another idea is that the weather got colder and the dinosaurs could not survive through the icy winters. [8]But this change of climate may have taken thousands or millions of years. [9]So why didn't the dinosaurs get used to the cold?

[10a]Some scientists think that [10b]a giant meteorite ten kilometres wide fell from space [10c]and hit our planet. [11a]The great explosion sent clouds of dust around the Earth [11b]and many animals died out within a few days.

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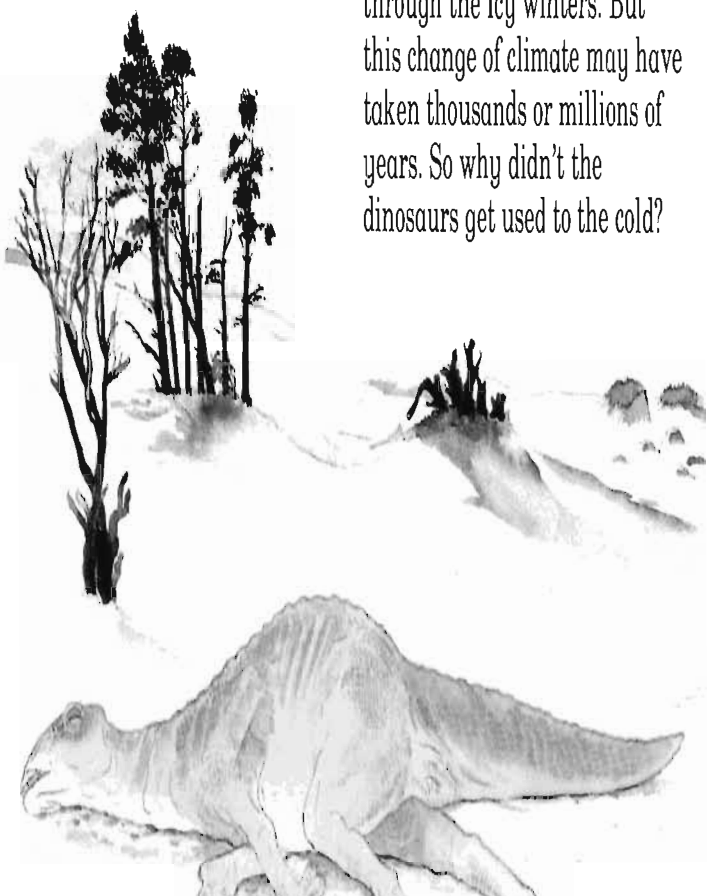

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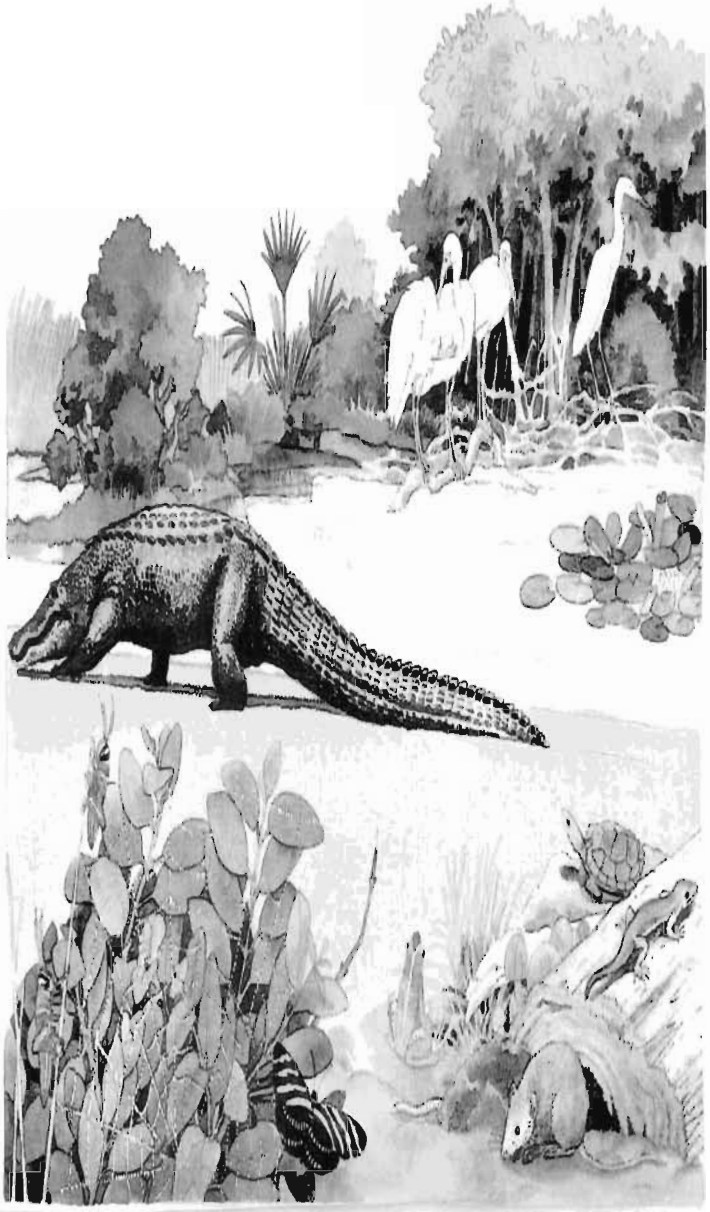

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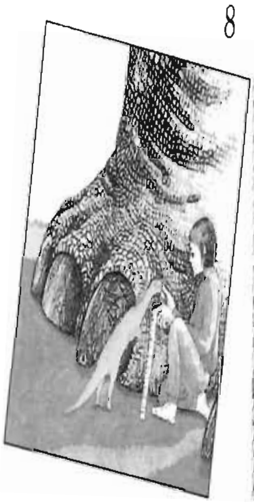

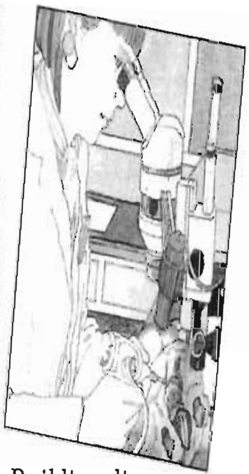

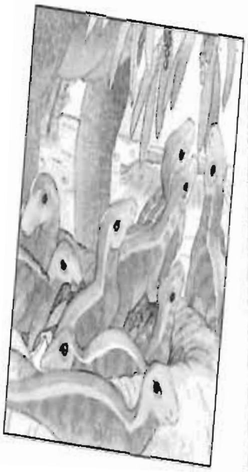

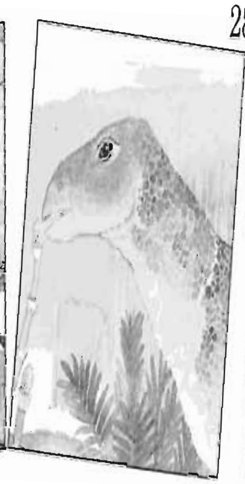

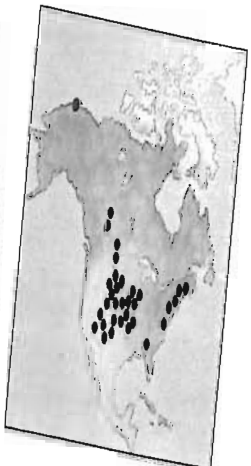

DK Direct Limited (ed.) (1993) *The Dorling Kindersley Picturepedia: Dinosaurs.* Dorling Kindersley: London, 46-47.

[1]Death of the Dinosaurs
[2]We can tell how old dinosaur fossils are [2b] by looking at the age of the rock they were found in [3a]From this, we know that [3b]the last of the dinosaurs died out about 65 million years ago. [4]But we can only guess why this happened. [5a]Perhaps a huge disaster wiped out all the dinosaurs in one go, [5b]or they may have become extinct over a very long time.

[6]**Rock Solid Proof**
[7]The rock on the Earth's surface is formed in layers. [8a]The deeper the layer, [8b]the older the rock. [9]No dinosaur fossil has been found above the layer that formed 65 million years ago. [10]This proves the last dinosaurs died this long ago.

[11]**From Outer Space**
[12a]Some scientists believe that [12b]a huge asteroid crashed into the Earth at the end of the Cretaceous Period. [13]Possible evidence for this has been found in Central America in Yucatán. [14]The huge impact of the asteroid could have spelled doom for the dinosaurs.

(*arrow pointing to picture of asteroid going towards Earth*)
[15]The asteroid may have hurtled towards Earth at about 241,350 kilometres per hour.

[16]**What a hole**
[17a]Scientists now think [17b]an asteroid hit Earth at the end of the Cretaceous period, [17c]making a crater in Yucatán that was 180 kilometres wide. [18]This photo shows a similar crater that was made by an asteroid in Arizona.

[19]**Finding Proof**
[20a]The asteroid crushed rock in the Earth's surface [20b]as it hit Yucatán. [21]Shocked quartz has been found at the crater site. [22]Iridium is a rare metal, found in asteroids. [23]There are high levels of iridium in the rock that contains the last dinosaur fossils.

(*arrow pointing to illustration of asteroid hitting Earth*)
[24]The disaster would have set off a chain reaction. [25a]400 million, million tonnes of rock and dust blocked out the Sun's light [25b]and the temperature dropped to -10°C. [26]Acid rain fell on the dinosaurs.

[27]**Slow change**
[28]Dinosaurs may not have disappeared overnight. [29a]The world's climate could have cooled over millions of years, [29b]slowly killing off the dinosaurs [30]New plants grew in this colder climate. [31]The warm jungles that covered most of the dinosaurs' world slowly turned into cooler forests.

DEATH OF THE DINOSAURS

We can tell how old dinosaur fossils are by looking at the age of the rock they were found in. From this, we know that the last of the dinosaurs died out about 65 million years ago. But we can only guess why this happened. Perhaps a huge disaster wiped out all the dinosaurs in one go, or they may have become extinct over a very long time.

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The rock on the Earth's surface is formed in layers. The deeper the layer, the older the rock. No dinosaur fossil has been found above the layer that formed 65 million years ago. This proves the last dinosaurs died this long ago.

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Some scientists believe that a huge asteroid crashed into the Earth at the end of the Cretaceous Period. Possible evidence for this has been found in Central America, in Yucatán. The huge impact of the asteroid could have spelled doom for the dinosaurs.

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Dinosaurs may not have disappeared overnight. The world's climate could have cooled over millions of years, slowly killing off the dinosaurs. New plants grew in this colder climate. The warm jungles that covered most of the dinosaurs' world slowly turned into cooler forests.

Wild Guesses
Many theories try to explain the death of the dinosaurs. Some are more unlikely than others! Perhaps peckish mammals ate their eggs.

Or perhaps the dinosaurs were poisoned by new, nasty plants. But no single theory can explain what really happened.

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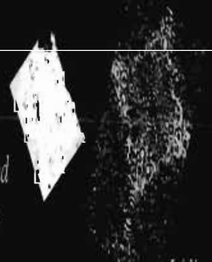
Scientists now think an asteroid hit Earth at the end of the Cretaceous Period, making a crater in Yucatán that was 180 kilometres wide. This photo shows a similar crater that was made by an asteroid in Arizona.



Shocked quartz

Iridium

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The asteroid crushed rock in the Earth's surface as it hit Yucatán. Shocked quartz has been found at the crater site. Iridium is a rare metal, found in asteroids. There are high levels of iridium in the rock that contains the last dinosaur fossils.

The Survivors
Life on Earth did not end with the death of the dinosaurs. Birds, mammals, reptiles and amphibians are some of the animal groups that survived, and are still around today.

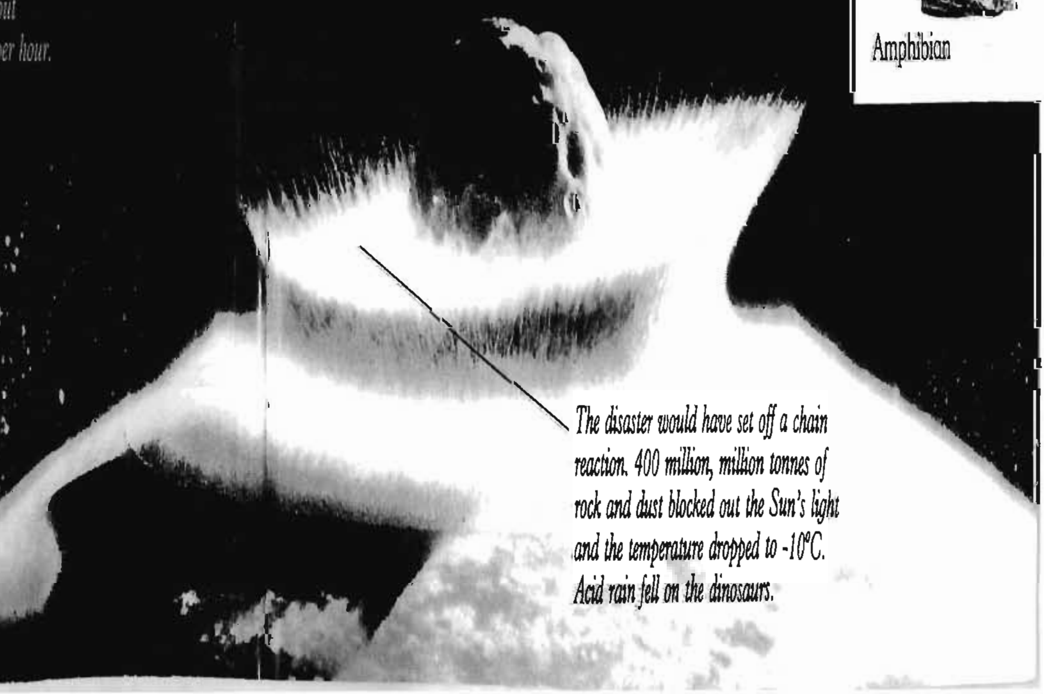
Bird

Mammal

Reptile

Amphibian

The asteroid may have hurtled towards Earth at about 241,350 kilometres per hour.



The disaster would have set off a chain reaction. 400 million, million tonnes of rock and dust blocked out the Sun's light and the temperature dropped to -10°C. Acid rain fell on the dinosaurs.

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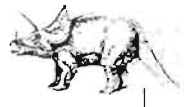

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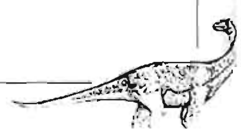

GLOSSARY

Asteroid A rock or metal object that orbits the Sun like a planet.

Bird-hipped Bird-hipped dinosaurs had hips rather like birds. The dinosaurs in this group were vegetarians.

Carnivore An animal that eats the flesh of another animal.

Carnosaur A big meat-eating theropod.

Cold-blooded Animals which depend on the Sun's heat to keep their body temperature level are 'cold-blooded'.

Conifer A tree with cones, for example a pine or fir.

Cretaceous The last period of the dinosaur age. It started about 140 million years ago, and ended about 65 million years ago.

Cycad A stumpy plant similar to a palm tree, which was very common during the dinosaur age.

Dinosaur A reptile that lived on land and walked with legs tucked underneath its body. The dinosaurs appeared in the Triassic Period. The last dinosaurs disappeared at the end of the Cretaceous Period.

Evolve All living things evolve over time. They change very slowly over a series of generations, to adapt to their environment.

Extinction The death of a whole group, or species, of animals.

Fossil The preserved remains of something that was once alive.

Gastrolith A stone swallowed to pound up food inside a dinosaur's stomach.

Hibernation Some animals fall into a deep sleep during the cold winter months to save energy. This is called hibernation.

Ichthyosaur A swimming reptile, very well adapted to life at sea.

Iridium A rare chemical element, found in meteorites and in the core of the Earth.

Jurassic The middle period of the dinosaur age. It started about 200 million years ago and ended about 140 million years ago.

Lizard-hipped Lizard-hipped dinosaurs had hips rather like those of modern lizards. The group included vegetarians and meat-eaters. It was one of the two main dinosaur groups.

Mammal Mammals are warm-blooded. They breathe air and feed their babies on milk. During the dinosaur age, all mammals were very small.

Migration The regular movement of animals from one place to another to find food or escape cold weather.

Placodont A turtle-like reptile of the Triassic seas.

Plesiosaur A sea reptile that used flippers to swim.

Pterosaur A flying reptile that lived at the same time as the dinosaurs, but was not a dinosaur.

Reptile A cold-blooded, egg-laying animal, covered with scales. Some prehistoric reptiles may have been warm-blooded, like the flying pterosaurs.

Sauropod Long-necked and long-tailed giant of the Jurassic and Cretaceous Periods.

Theropod A meat-eating, lizard-hipped dinosaur. Most theropods stood upright on two legs.

Triassic The first part of the dinosaur age. It lasted from about 245 to 200 million years ago. The first dinosaurs evolved during the Triassic Period.

Warm-blooded Animals that can control their body temperature inside their bodies, without depending on the Sun for constant heat, are warm-blooded.

Acknowledgements

Photography: Peter Chadwick, Andy Crawford, John Downes, Lynton Gardiner, Colin Keates, The Colour Company, Tim Kelly, Gary Kevin, Chris King, Dave King, Cyril Laubscher, Kevin Mallett, Ray Moller, Tim Ridley, Dave Rudkin, Karl Shone, Harry Taylor and Andreas Von Einsiedel.

Illustration: Roby Braun, Jim Channell, Roy Flooks, Linden Artists, Alan Male, Richard Manning, Jane Pickering, Simon Roulstone and John Temperton.

Models: Roby Braun; Crystal Palace Park, London; Donks Models; Graham High/Centaur Studios: Brachiosaurus, Iguanodon, Triceratops; John Holmes; Jeremy Hunt/Centaur Studios: Barosaurus, Baryonyx, Corythosaurus; Norrie Carr Model Agency; Reconstruction of Dimorphodon by Arril Johnson for Bristol City Museums & Art Gallery; Scallywags Model Agency.

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tl – top left
cra – centre right above
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crb – centre right below
tc – top centre
cla – centre left above
cl – centre left
bl – bottom left
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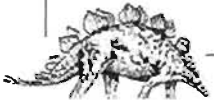


P·I·C·T·U·R·E·P·E·D·I·A

NOTE TO PARENTS

This book is part of PICTUREPEDIA, a completely new kind of information series for children. Its unique combination of pictures and words encourages children to use their eyes to discover and explore the world, while introducing them to a wealth of basic knowledge. Clear, straightforward text explains each picture thoroughly and provides additional information about the topic.

'Looking it up' becomes an easy task with PICTUREPEDIA, an ideal first reference for all types of schoolwork. Because PICTUREPEDIA is also entertaining, children will enjoy reading its words and looking at its pictures over and over again. You can encourage and stimulate further inquiry by helping your child pose simple questions for the whole family to 'look up' and answer together.

Johnson, Jinny (1996) *Prehistoric Life* London: Marshall Publishing Ltd., 22-23.

[1]What went wrong?
[2a]When dinosaurs became extinct at the end of the Cretaceous period, 65 million years ago, [2b]so did a number of other groups, such as pterosaurs, marine plesiosaurs and many tiny forms of sea life (plankton). [3]But not all living things were affected. [4]Fish, crocodiles, turtles, birds, mammals and most flowering plants managed to survive unchanged.

[5a]Because these extinctions happened 65 million years ago, [5b]no one knows whether they took place over several hundred thousand years, a few thousand years or within a century. [6a]Some scientists think that [6b]dinosaurs, and other groups that became extinct, were becoming less numerous and varied for several million years before the final extinction. [7a]They believe that [7b]the climate may have become cooler, [7c]perhaps because the seas were draining back from the continents [7d]and because the many volcanic eruptions at the time were throwing up great quantities of dust into the atmosphere.

Captions of 3 illustrations on page 22:
[8]The huge impact of a large meteorite would have caused earthquakes and tidal waves as well as dust fallout.

[9]The Yucatán area of Mexico may have been the site of the meteorite impact.

[10]This meteorite crater is 1.2 kilometres wide. [11]The Cretaceous meteorite could have made a crater 150 times this size.

[12]Meteorite impact
[13]But there is also evidence that a great meteorite, measuring some 9.5 kilometres across, struck the Earth at the time of the Cretaceous extinctions. [14]A huge crater that could have been caused by such an impact has been found near the north coast of Mexico. [15]Rocks all over the world laid down at that time contain unusual minerals which could have come from the material of the meteorite, thrown up into the atmosphere after the enormous impact.

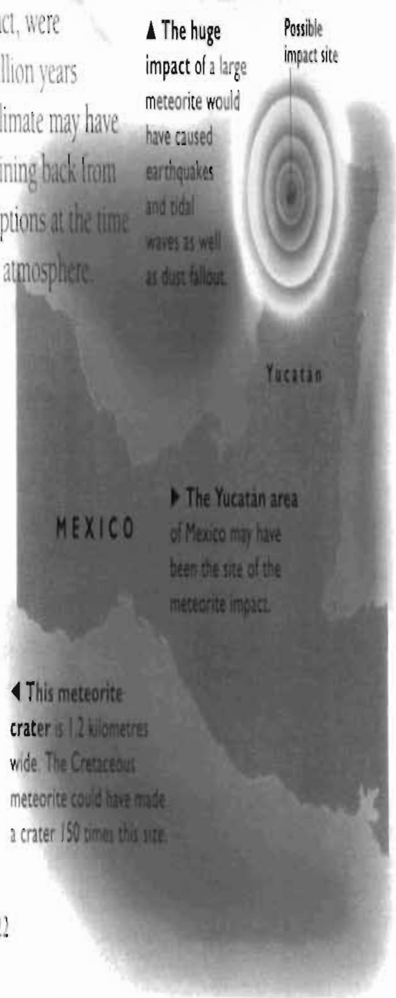
[16a]This debris could have darkened the skies for many years, [16b]causing a long, cold winter. [17]Many of the plants, both on land and in the sea, would have died from lack of light. [18]Then the plant-eating dinosaurs died in their turn, followed by the carnivorous dinosaurs that ate them.

[19]"Greenhouse effect"
[20a]Even after the thicker dust had settled [20b]and the long winter ended, [20c]the atmosphere would still have contained a lot of finer dust from the rocks thrown up by the force of the impact. [21a]These would have caused what scientists call a "greenhouse effect", [21b]making the climate much hotter. [22]These two climatic changes would have caused very rapid extinctions, especially of larger animals that needed more food. [23]It is possible that both groups of scientists are right and the dinosaurs were already becoming less successful

What went wrong?

When dinosaurs became extinct at the end of the Cretaceous period, 65 million years ago, so did a number of other groups, such as pterosaurs, marine plesiosaurs and many tiny forms of sea life (plankton). But not all living things were affected. Fish, crocodiles, turtles, birds, mammals and most flowering plants managed to survive unchanged.

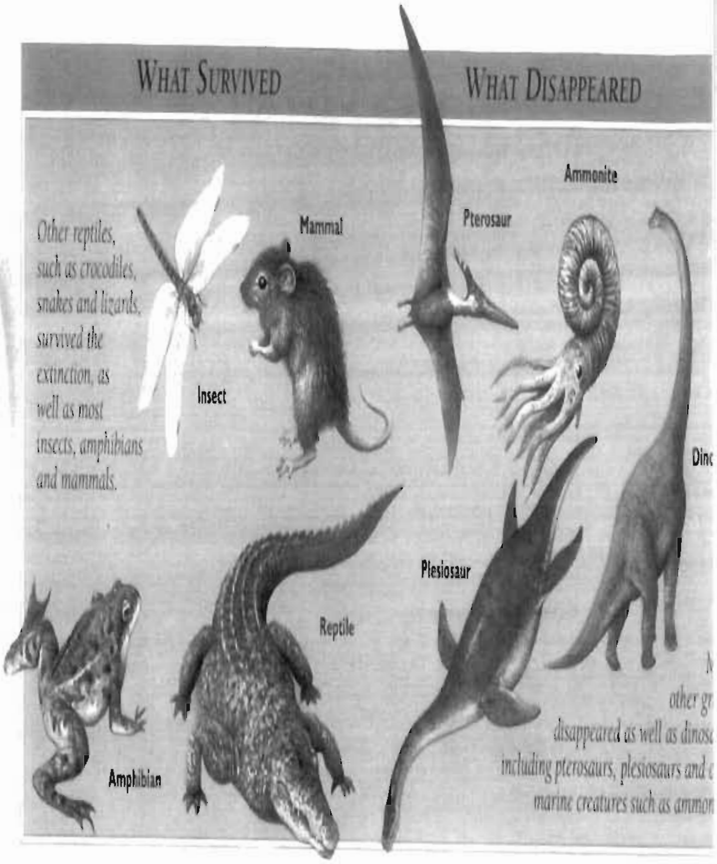
Because these extinctions happened 65 million years ago, no one knows whether they took place over several hundred thousand years, a few thousand years or within a century. Some scientists think that dinosaurs, and the other groups that became extinct, were becoming less numerous and varied for several million years before the final extinction. They believe that the climate may have become cooler, perhaps because the seas were draining back from the continents and because the many volcanic eruptions at the time were throwing up great quantities of dust into the atmosphere.



▲ **The huge impact** of a large meteorite would have caused earthquakes and tidal waves as well as dust fallout.

▶ **The Yucatán area** of Mexico may have been the site of the meteorite impact.

◀ **This meteorite crater** is 1.2 kilometres wide. The Cretaceous meteorite could have made a crater 150 times this size.



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This debris could have darkened the skies for many years, causing a long, cold winter. Many of the plants, both on land and in the sea, would have died from lack of light. Then the plant-eating dinosaurs died in their turn, followed by the carnivorous dinosaurs that ate them.

"Greenhouse effect"

Even after the thicker dust had settled and the long winter ended, the atmosphere would still have contained a lot of finer dust from the rocks thrown up by the force of the impact. These would have caused what scientists call a "greenhouse effect", making the climate much hotter. These two climatic changes would have caused very rapid extinctions, especially of larger animals that needed more food.

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▲ **This fossilised shell** belonged t squidlike creature called an ammonit before their final end, announced by the fiery glow of a huge meteor streaking across the sky.

Captions of 3 illustrations on page 23:
[24]This fossilised shell belonged to a squidlike creature called an ammonite.

[25]Other reptiles such as crocodiles, snakes and lizards, survived the extinction, as well as most insects, amphibians and mammals.

[26]Many other groups disappeared as well as dinosaurs, including pterosaurs, plesiosaurs and other marine creatures such as ammonites.

Taylor, David. (1993) The Prehistoric World of the Dinosaurs: Tyrannosaurus Rex Boxtree: London, 26-29.

[1]**The end of the Dinosaurs?**
[2a]At the end of the age of the dinosaurs, an asteroid streaked out of space [2b]and collided with the Earth. [3a]The earth shuddered [3b]and great trees crashed to the ground. [4a]The sun danced in the sky [4b]and then suddenly was gone. [5a]The sky became black [5b]and there was the darkness of early night, [5c]but no moon or stars, just the glow of volcanoes. [6]And there was the smell of hot dust and burning.

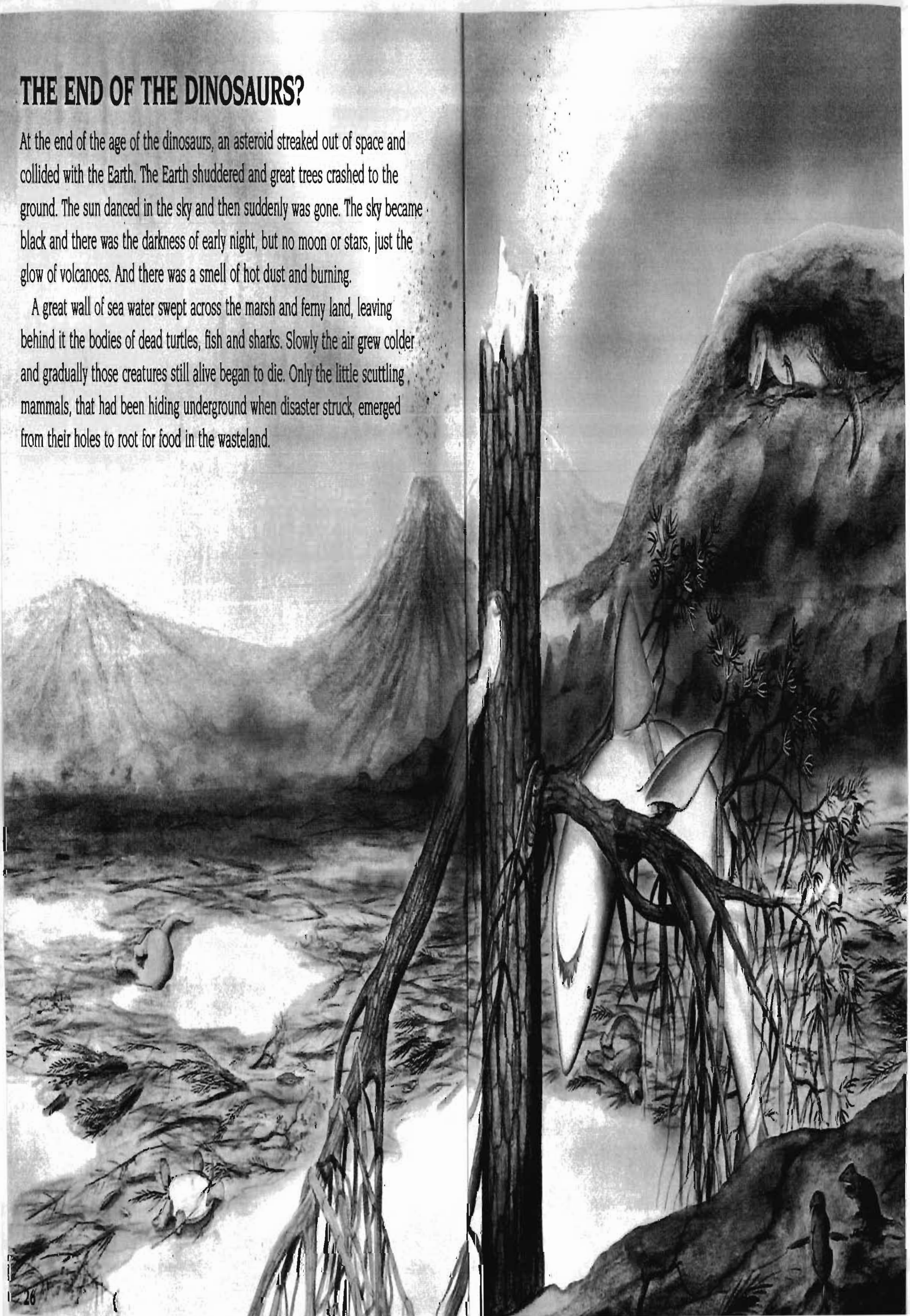
[7a]A great wall of sea water swept across the marsh and ferny land [7b]leaving behind it the bodies of dead turtles fish and sharks. [8a]Slowly the air grew colder [8b]and gradually those creatures still alive began to die. [9a]Only the little scuttling mammals, that had been hiding underground when disaster struck, emerged from their holes [9b]to root for food in the wasteland.

α Illustration dead dinosaurs sharks and turtles and living mice in a devastated landscape

THE END OF THE DINOSAURS?

At the end of the age of the dinosaurs, an asteroid streaked out of space and collided with the Earth. The Earth shuddered and great trees crashed to the ground. The sun danced in the sky and then suddenly was gone. The sky became black and there was the darkness of early night, but no moon or stars, just the glow of volcanoes. And there was a smell of hot dust and burning.

A great wall of sea water swept across the marsh and ferny land, leaving behind it the bodies of dead turtles, fish and sharks. Slowly the air grew colder and gradually those creatures still alive began to die. Only the little scuttling mammals, that had been hiding underground when disaster struck, emerged from their holes to root for food in the wasteland.



[10]Impact
[11]Asteroids are lumps of rock in orbit round the sun. [12]There are literally millions of them, some no bigger than an apple, others 20kms in diameter. [13a]Should the orbit of an asteroid cross that of the Earth [13b]as it, too, moves around the Sun, [13c]a collision is possible. [14a]Because these pieces of space junk travel at about 80,000 kph, [14b]the effect of the impact is devastating. [15]An asteroid 100 metres in diameter would blast a crater 2 kms across and 100 metres deep - similar to the hole created by just such an event 40,000 years ago in Arizona, USA. [16a]Asteroids 1 km across hit the Earth on average every 100,000 years[16b] while giant ones, 20km across, hit every 10 to 100 million years or so.

β illustration of an asteroid exploding and a large crater

[17]The end of an era
[18a]There are many theories [18b]about why the dinosaurs died out. [19a]All the alternative theories have their weak points, [19b]and the arguments continue. [20]Some of the theories are as follows:

1. [21a]The dinosaurs starved to death [21b]because moth and butterfly caterpillars ate most of the vegetation
2. [22]The mammals fed on dinosaur eggs
3. [23]The dinosaurs were poisoned by some of the new kinds of plants that evolved.
4. [24]There was an epidemic
5. [25]The gradual warming of the Earth caused cataracts that affected the eyes of the dinosaurs and blinded them.
6. [26]The dinosaurs died because of the intense radiation coming from outer space.

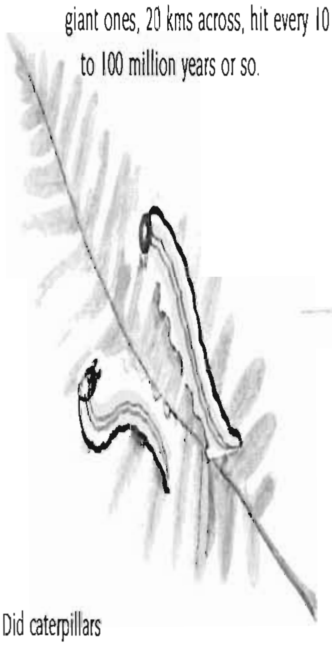
[27]The dark of night
[28a]There would have been an unimaginable explosion [28b]as the asteroid landed [28c]and was blown to smithereens. [29]A pall of dust would have been cast up into the atmosphere that would have persisted for months. [30a]Darkness would have descended on the land [30b]and plant life, denied sunlight would have died, followed shortly by the animals that fed on it and, in turn, by the predators that fed on them.

χ Illustration with the caption: Did caterpillars eat all the vegetation?

δ Illustration with the caption: Did mammals like Megazastrodon eat the dinosaurs' eggs?

Impact!

Asteroids are lumps of rock in orbit round the Sun. There are literally millions of them, some no bigger than an apple, others 20 kms in diameter. Should the orbit of an asteroid cross that of the Earth as it, too, moves round the Sun, a collision is possible. Because these pieces of space junk travel at about 80,000 kph, the effect of the impact is devastating. An asteroid 100 metres in diameter would blast a crater 2 kms across and 100 metres deep – similar to the hole created by just such an event 40,000 years ago in Arizona, USA. Asteroids 1 km across hit the Earth on average every 100,000 years while giant ones, 20 kms across, hit every 10 to 100 million years or so.



Did caterpillars eat all the vegetation?

The end of an era

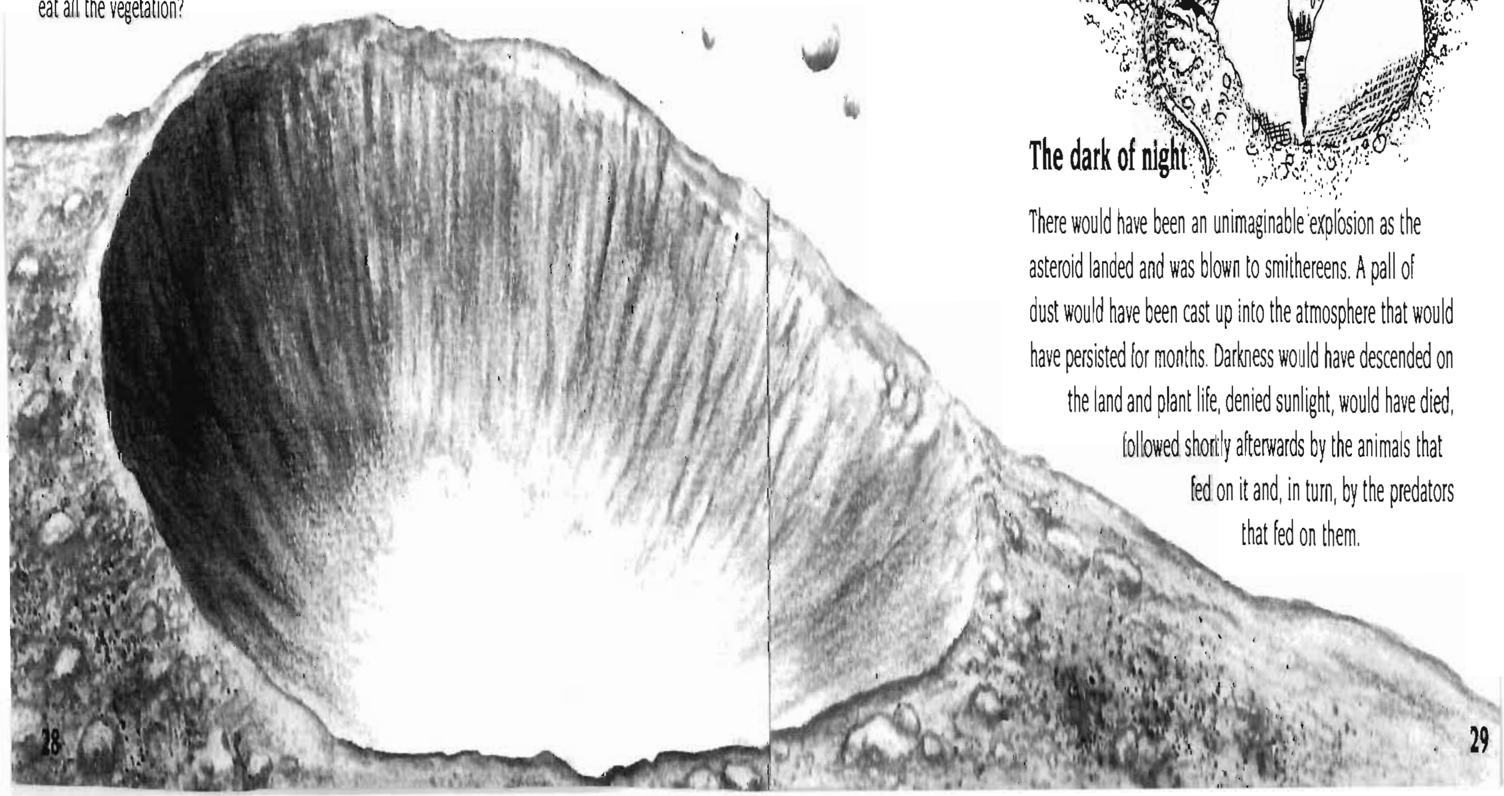
There are many theories about why the dinosaurs died out. All the alternative theories have their weak points, and the arguments continue. Some of the theories are as follows:

1. The dinosaurs starved to death because moth and butterfly caterpillars ate most of the vegetation.
2. The mammals fed on dinosaur eggs.
3. The dinosaurs were poisoned by some of the new kinds of plants that evolved.
4. There was an epidemic.
5. The gradual warming of the Earth caused cataracts that affected the eyes of the dinosaurs and blinded them.
6. The dinosaurs died because of intense radiation coming from outer space.

Did mammals like Megazastrodon eat the dinosaurs' eggs?

The dark of night

There would have been an unimaginable explosion as the asteroid landed and was blown to smithereens. A pall of dust would have been cast up into the atmosphere that would have persisted for months. Darkness would have descended on the land and plant life, denied sunlight, would have died, followed shortly afterwards by the animals that fed on it and, in turn, by the predators that fed on them.



Biochemistry Practical Report: Column Chromatography

Introduction

A Russian botanist, Tswett, first used chromatography to describe the separation of coloured plant pigments on a column of alumina, hence the meaning of the word, "coloured writing."
Chromatography is a technique used to separate compounds according to their size, shape, mass, charge, solubility and absorption properties. There are many different types of chromatography, each of which separates compounds according to different physical properties. However, all types of chromatography involve interactions between 3 components: the mixture to be separated, the solid phase and the solvent. It is important to note that not all compounds behave as expected in theory, but trial and error must be employed to find the best method for separating each type of compound.[1]

Column chromatography is a common method for separating biochemical mixtures. Usually long, narrow columns are used since they show the highest resolutions, but when large samples need to be fractionated, short, squat columns may be used to speed up the fractionation, and because they can hold greater quantities of sample. Columns are usually made of glass, but may also be made of plastic or steel.

When pouring the column, it is filled to about one-third with the solvent. A slurry of the packing material is then carefully added by pouring down a glass rod to prevent air bubbles being trapped in the column.[1] It is allowed to settle before running off the excess solvent and the process is repeated until the column is the required height. The packing material must be thoroughly washed with the solvent to remove excess particles which may run down with the sample to be fractionated and contaminate the results. The level of the solvent is kept just above that of the packing material to prevent it hardening in the column.[2]

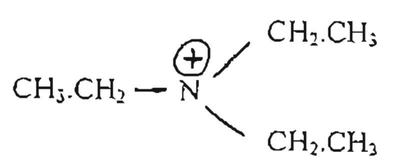
The sample is then pipetted onto the surface of the column taking care not to disturb the packing material. A test tube is placed below the column and the tap at the base opened. More solvent is pipetted or syringed into the top of the column to ensure that as sample and solvent elute, the column is never left dry to harden. The test tubes are replace periodically to ensure a spread of the molecules being separated and each fraction is analyzed and an elution profile prepared.

Separation of serum proteins by ion exchange chromatography

Ion exchange, which separates biochemical compounds on the basis of their charge, is one method of column chromatography.

Resin beads, which have a very high charge density, are used for removing inorganic cations from water. However, they have a tendency to denature most proteins. Therefore porous matrices, such as cellulose, dextrans, agarose or polyacrylamide, substituted with a low number of suitable isonable groups, are used for biochemical purposes so as to retain proteins. In this practical DEAE-cellulose is used.[2]

In DEAE-cellulose, substituted quaternary ammonium groups (diethylaminoethyl – $CH_2CH_2N^+H(C_2H_5)_2$) are chemically linked to cellulose fibres. Since these groups have a positive charge they allow the DEAE-cellulose matrix to be a cation exchanger.[2]



diethyaminoethyl

Different molecules are removed from the column by altering the ionic strength of the buffer passing through. This creates greater competition for the positively charged groups of the matrix and releases bound molecules which have a negative charge. In this experiment increasing salt (NaCl) concentrations are used in the elution buffer creating a stepped salt gradient.

Apparatus

CEAE-cellulose matrix (3 cm) in 20 cm x 1 cm chromatography column
Eluting buffer: 0.01 M sodium phosphate (pH 7.0)
Eluting solutions: Elution buffer containing 0.1 M NaCl
Elution buffer containing 0.2 M NaCl
Elution buffer containing 0.3 M NaCl
Sheep or bovine serum
Syringes with rubber tubing attached
Test tubes and test tube racks
Wax pencil
UV spectrophotometer & quartz cuvettes

Method

The tap was opened to allow the eluting buffer to run out until it was about 0.5 cm above the bed surface. 20 test tubes were numbered and marked to hold 3 ml. 0.5 ml serum was loaded onto the bed surface using a syringe with rubber tubing attached, the tap opened and test tube 1 placed beneath it. More eluting buffer was added to the bed surface to replace that which came out with the sample at the bottom of the column.

When test tube 1 was filled to the 3 ml mark, it was replaced with test tube 2. As each test tube was removed it was analyzed for the presence of proteins with the spectrophotometer at a wavelength of 280 nm(UV light)[3]. The eluting buffer was placed in a quartz cuvette and the machine calibrated using it as a blank. Whenever the absorbance started to decline, an eluting solution with a greater salt concentration was used to release more bound protein molecules.

Results

Table showing ~~The~~ the absorbance of protein contained in the different fractions of serum using a spectrophotometer at a wavelength of 280nm

Sample Number	Absorbance	Volume Eluted (ml)	Elution buffer used for reference
1	~~21.300~~	3	0.01 M sodium phosphate
2	Sample missing	6	0.01 M sodium phosphate
3	0.254	9	0.01 M sodium phosphate
4	0.297	12	0.01 M sodium phosphate with 0.1M NaCl
5	0.442	15	0.01 M sodium phosphate with 0.1M NaCl
6	0.341	18	0.01 M sodium phosphate with 0.1M NaCl
7	0.008	21	0.01 M sodium phosphate with 0.1M NaCl
8	-0.018	24	0.01 M sodium phosphate with 0.1M NaCl
9	0.116	27	0.01 M sodium phosphate with 0.2M NaCl
10	0.160	30	0.01 M sodium phosphate with 0.2M NaCl
11	0.030	33	0.01 M sodium phosphate with 0.2M NaCl
12	0.013	36	0.01 M sodium phosphate with 0.2M NaCl
13	0.019	39	0.01 M sodium phosphate with 0.2M NaCl
14	0.023	42	0.01 M sodium phosphate with 0.2M NaCl
15	0.043	45	0.01 M sodium phosphate with 0.3M NaCl
16	-0.060	48	0.01 M sodium phosphate with 0.3M NaCl
17	-0.057	51	0.01 M sodium phosphate with 0.3M NaCl
18	0.026	54	0.01 M sodium phosphate with 0.3M NaCl
19	0.014	57	0.01 M sodium phosphate with 0.3M NaCl
20	0.017	60	0.01 M sodium phosphate with 0.3M NaCl

Absorbance of original serum

The original serum was too concentrated to measure with the spectrophotometer and had to be diluted.

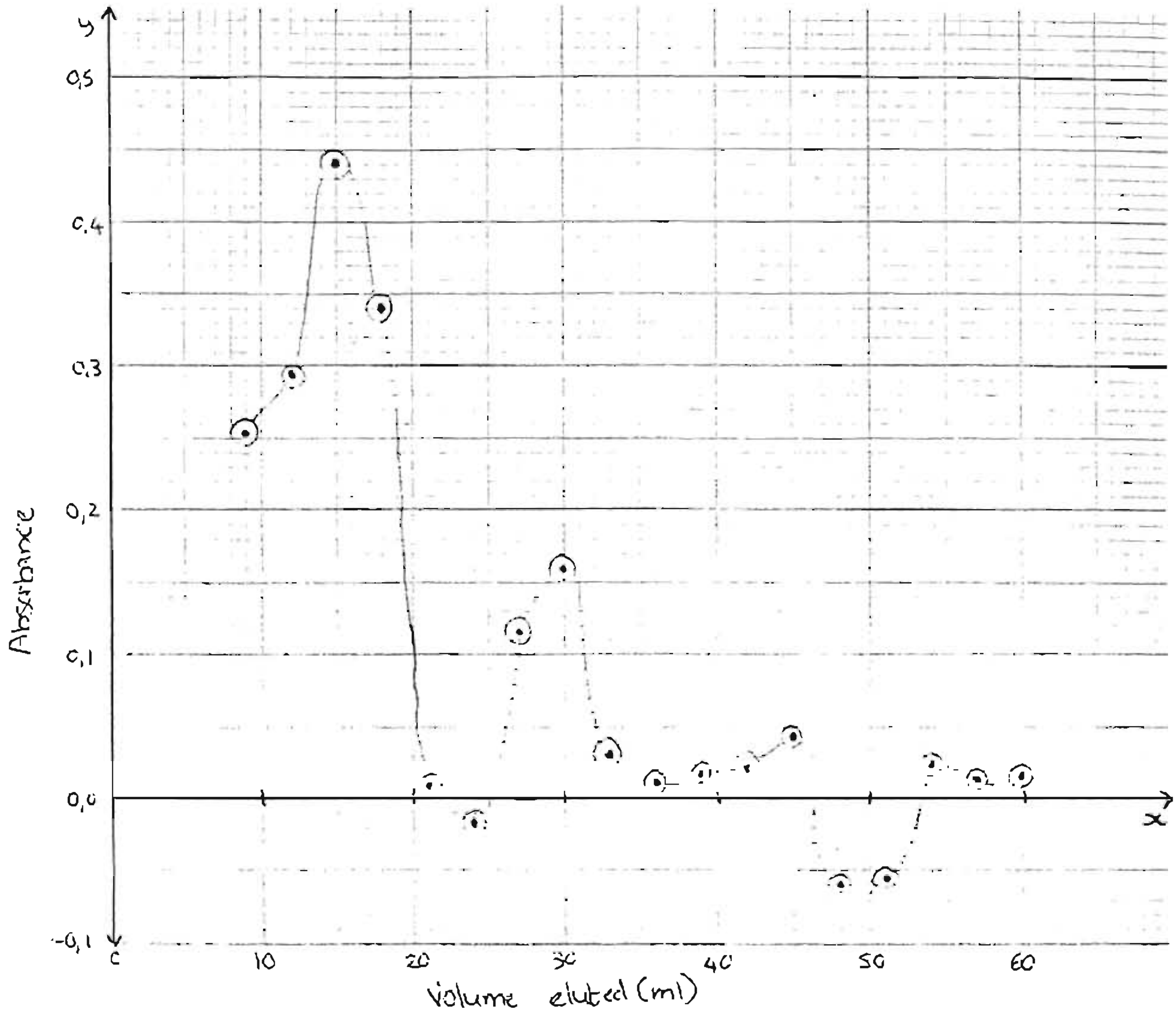
5 times – too concentrated
10 times – too concentrates
100 times – Absorbance = 1.387

∴ Absorbance of sample = 1.387 x 100 = 138.700

Recovery of protein from column

Recovery of protein = sum of absorbance in all the test tubes = 22.968

Chromatogram showing the absorbance of proteins from serum at a wavelength of 280 nm
Only showing the absorbance of sample 3 to 20



Cartoon

"It's probably part of the hype for 'Meteor'."