DIAGRAMMATICS:

an investigation aimed at providing
a theoretical framework for studying diagrams
and for establishing a taxonomy of their
fundamental modes of graphic organization

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## Contents list

Acknowledgements  
Note of conventions and abbreviations  
Abstract  
Expanded contents list

### Chapters

1. INTRODUCTION  
2. PREVIOUS STUDIES AND PRESENT METHODOLOGY  
3. PROPOSED METHOD OF ANALYSING DIAGRAMS  
4. PROBLEMS CONCERNING THEORIES OF PICTURING  
5. MODE OF DIAGRAMMATIC CORRESPONDENCE  
6. METAPHOR IN DIAGRAMS  
7. MODE OF DIAGRAMMATIC DEPICTION  
8. MODE OF DIAGRAMMATIC ORGANIZATION  
9. AUDITS OF SPECIMEN DIAGRAMS  
10. CONCLUSIONS AND IMPLICATIONS FOR DESIGNERS

### Bibliography

### Appendices

A. DIAGRAM SOURCES  
B. ADDITIONAL DIAGRAM AUDITS  
C. PUBLICATIONS BY THE AUTHOR  
D. AUTHOR'S CURRICULUM VITAE
Acknowledgements

Necessarily an investigation of the sort reported in this dissertation draws heavily on the publications of others. These authors are acknowledged by references at appropriate places in the text, and their works are listed in the Bibliography. The sources of the figures are given in accompanying captions (where the source is not indicated the illustration has been produced by me).

Certain personalities have played a special role in the progress of the work described here and particular mention of these people must be made.

I am indebted to Professor Herbert Spencer for his support of this project, and for providing me with the necessary supervisors from the academic staff of the School of Graphic Arts at the Royal College of Art.

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Note on conventions and abbreviations

One or two novel features have been used for the presentation of this dissertation, and these are now described, together with the more usual conventions which have been adopted for this work.

Indicators on the foredge of the 'Contents list' page align with marks on corresponding pages in the rest of the volume, showing the location of each chapter, the Bibliography, and each appendix.

Chapters are sub-divided into sections. Each new section starts on a new page with a section heading. Each heading carries a decimal number, the prefix corresponding to the chapter number. Sub-headings have been used in places, but these are not numbered. All section headings within a chapter are listed in the chapter opening as well as in the 'Expanded contents list' which follows the Abstract.

The numbers of figures are hyphenated and again the prefix corresponds to the chapter number. A similar scheme is used for the page numbers where the chapter number is separated from the individual page number by an oblique stroke.

The hanging notes, which appear in the margins, are referred to in the text by numbers in square brackets. The numbering starts at '1' for each chapter. These notes always start on the page where they are cited and in most cases align with their reference number in the text.

References to previous publications are given using the Harvard method; that is, by citing the name or names of the authors and the year of publication. This may be followed by page numbers. All this information appears in parentheses except where the author's name is part of a
sentence. In this case just the date and page numbers are enclosed. The exceptions to this scheme are references to the works of Charles Sanders Peirce. His writings are all to be found in the several volumes of his collected works. In these volumes each paragraph is numbered, so references to Peirce will be given as volume numbers followed by paragraph numbers, as in the following example: Peirce (4.350). Parentheses are also used in the usual grammatical way.

As the Harvard method of referencing has been adopted, the Bibliography has been arranged alphabetically by author. Where there are several works by the same author, they are listed chronologically by date. In those cases where an author has a number of publications in one year, the dates carry the suffix 'a' or 'b' etc.

Quotations appear in single quotation marks, and quotations within quotations appear in double quotation marks. My insertions into quotations, given to aid the sense in the present context, appear in square brackets. Single quotation marks are also used when introducing words which have either been given a special technical sense by other authors or have been coined by other authors.

Words to which I have given a special technical sense, or which I have coined, are underlined when they are first introduced.

Underlining is also used in cases where italics would have been used had they been available; for example, to indicate the title of a book or journal, for words normally regarded as foreign, and for sub-headings when they are occasionally used. In some cases this convention has also been used to give emphasis.

The following abbreviations have been adopted:

cf compare
et al and others
ff following pages
ibid in the same place
nd no date
op cit in the work cited
p page
pp pages
Abstract

The thesis presented in this dissertation is concerned with the graphic characteristics of diagrams, and the relation between those characteristics and the way diagrams may be interpreted by their intended readers. The dissertation is essentially theoretical in character.

In the first instance the thesis is directed at designers and teachers interested in the graphic presentation of information, but it is expected that the work will also prove to be of interest to researchers working in graphic communication.

The case is made for 'ground-clearing scholarship' as diagrams have rarely been the subject of any serious investigation. Part of the aim of the work is to provide a useful theoretical framework, and a precise terminology, for study in the subject area of diagrammatics.

A process of auditing diagrams is proposed which is aimed at isolating the fundamental modes of graphic organization available for certain classes of diagram. The auditing process is carried out in two stages. First, the diagram is analysed into its significant elements. Then the significant elements are classified in terms of certain categories. These categories are derived from the three levels of semiotic analysis known as 'pragmatic', 'semantic', and 'syntactic' (Morris 1938).

At the pragmatic level, each significant element is classified in terms of its mode of correspondence. The mode of correspondence is a continuum ranging from the literal, through the semi-literal, to the non-literal. It is proposed that the non-literal mode of correspondence makes use of what may be called graphic metaphor. At the semantic level, each significant element is classified in terms of its mode of depiction. This is also a continuum ranging from the figurative, through the semi-figurative,
to the non-figurative. The mode of depiction has parallels with Moles (1968) 'scales of iconicity'.

Next each relational feature of each significant element is classified in terms of its modes of organization. This category of classification is at the syntactic level.

A large sample of specimen diagrams has been collected and examined. The audit process has been applied to a small number of diagrams taken from the sample. It seems that those diagrams which are primarily non-literal in their mode of correspondence, and non-figurative in the mode of depiction, are restricted to three fundamental modes of organization which may be present in various mixtures. These modes of organization are those which can be used to express the ideas of association, sequence, and value, and have the graphic characteristics of grouping, linking, and variation, respectively.

The identification of these modes of organization, and their relations to the modes of correspondence and depiction, is regarded as the principal outcome of the work reported. The relationship between the modes of correspondence, depiction, and organization is presented in the form of a three-dimensional, taxonomic model.

It is further proposed that the modes of organization identified in the course of this investigation can be used by designers as a basis for generating alternative diagrammatic structures.
## Expanded contents list

### Chapter 1 INTRODUCTION
1.1 Background p1/1
1.2 Diagrams as a subject of inquiry p1/2
1.3 Aim of the study p1/4
1.4 Organization of this dissertation p1/9
Summary p1/12

### Chapter 2 PREVIOUS STUDIES AND PRESENT METHODOLOGY
2.1 Definitions of 'diagram' p2/1
2.2 Previous studies p2/5
2.3 Present methodology p2/15
Summary p2/20

### Chapter 3 PROPOSED METHOD OF ANALYSING DIAGRAMS
3.1 A linguistic approach p3/1
3.2 Significant elements in diagrams p3/12
3.3 Parsing diagrams p3/20
3.4 Noun and verb spaces p3/25
3.5 Syntactics, semantics, and pragmatics p3/30
Summary p3/34

### Chapter 4 PROBLEMS CONCERNING THEORIES OF PICTURING
4.1 Problems of iconism p4/1
4.2 An iconoclastic view p4/2
4.3 Critique of iconism p4/20
4.4 Generative theory p4/24
4.5 Similitude in diagrams p4/29
Summary p4/33

### Chapter 5 MODE OF DIAGRAMMATIC CORRESPONDENCE
5.1 Literal correspondence p5/1
5.2 Semi-literal correspondence p5/9
5.3 Non-literal correspondence p5/15
Summary p5/20
Chapter 6 METAPHOR IN DIAGRAMS
6.1 Metaphor in language p6/1
6.2 The nature of metaphor in diagrams p6/9
6.3 The value of metaphor in diagrams p6/17
6.4 Convention and metaphor in diagrams p6/25
6.5 Rhetoric in diagrams p6/31
6.6 Mnemonic diagrams p6/37
Summary p6/39

Chapter 7 MODE OF DIAGRAMMATIC DEPICTION
7.1 Abstraction in diagrams p7/1
7.2 Schematization in diagrams p7/3
7.3 Modes of depiction p7/6
Summary p7/10

Chapter 8 MODE OF DIAGRAMMATIC ORGANIZATION
8.1 Modes of interpretation p8/1
8.2 Modes of organization p8/4
8.3 Grouping in diagrams p8/8
8.4 Linking in diagrams p8/15
8.5 Variation in diagrams p8/26
8.6 Mixed modes of organization p8/42
Summary p8/46

Chapter 9 AUDITS OF SPECIMEN DIAGRAMS
9.1 Classification of relational features p9/1
9.2 The auditing process p9/8
9.3 Audit of the 'History of Miyano' diagram p9/13
9.4 Audit of the 'Mental personality' diagram p9/20
9.5 Comments on the diagram audits p9/32
Summary p9/35

Chapter 10 CONCLUSIONS AND IMPLICATIONS FOR DESIGNERS
10.1 The nature of diagrams p10/1
10.2 Relations between the interpretive modes p10/6
10.3 Value of the figurative and non-literal modes p10/10
10.4 Implications for diagram designers p10/16
10.5 Future research p10/22
Summary p10/27

Bibliography pBib/0
Appendix A  DIAGRAM SOURCES
   A.1  Books  pA/1
   A.2  Periodicals  pA/4

Appendix B  ADDITIONAL DIAGRAM AUDITS
   B.1  Sensory homunculus  pB/1
   B.2  Diagram of lines (January 1953)  pB/10
   B.3  Universal affirmative proposition  pB/18
   B.4  Computer program flow chart  pB/20
   B.5  ISOTYPE chart on working hours in Sweden  pB/23

Appendix C  PUBLICATIONS BY THE AUTHOR
   C.1  List of publications  pC/1
   C.2  Reprint from the Information Design Journal  pC/4

Appendix D  AUTHOR'S CURRICULUM VITAE
Chapter 1 INTRODUCTION

1.1 Background

1.2 Diagrams as a subject of inquiry

1.3 Aim of the study

1.4 Organization of this dissertation

Summary

'Two-fold path to enlightenment? Sign in the garden of the Heian Shrine, Kyoto, Japan, photographed by reader Gerald Drucker, winner of this week's £10 prize.'
From: Sunday Observer
24 December 1978

順 路

THIS WAY
1.1 Background

Much of the work carried out on graphic design courses is characterized by the intention to amuse, delight, persuade, invigorate, provoke or otherwise stimulate [1]. In recent years there has been a growing interest in the design of material which is characterized by its intention to describe, explain, inform or instruct. This area of activity is now widely referred to as information design. Interest in it has manifested itself by the establishment of a number of graphic design courses with a declared bias towards this type of work. The Royal College of Art established the UK's first post-graduate course specializing in graphic information design [2]. Courses dealing with this topic are emerging partly because of an increasing awareness of the useful role that information designers can play in society, and partly in response to the increasing employment opportunities for designers skilled in dealing with graphics of this nature. Evidence of these opportunities is provided by the vast amount of popular illustrated works of an educational nature produced by book publishers. Consider for example the Mitchell Beazley Joy of Knowledge series of books which is encyclopedic in character and makes extensive use of colourful diagrams [3]. It is the product of a small army of writers, designers and illustrators. There are of course many other types of work the designer of informative graphics can engage in, using various media and serving a variety of user groups.

There seem to be a number of different sorts of representation available for informative graphics: words in the form of type matter, pictorial illustrations which describe the appearance of objects, symbols which assert the presence of something or act as indicators, and diagrams which sometimes seem to be a sort of composite of the previous three [4]. All these sorts of representation seem to have been the topic of extensive investigation with the exception of diagrams.

[1] Some insights to the teaching of design in British art schools are given by Potter (1980). See also Baynes (1983).

[2] The Royal College of Art is an exclusively post-graduate institution. Its long established Department of Illustration deals with 'Illustration in any of its aspects other than technical illustration' (Royal College of Art Calendar 1974-75 p77). With the formation of the Department of Graphic Information in 1976, the work of the college now extends into areas which might well be described as Technical Illustration.

[3] Titles in the 'Joy of Knowledge' series include: Science and the Universe, History and culture, Men and society (see Appendix A).

[4] Cf note 7 of Marcus (1977) who observes that whilst the OED's definitions of 'diagram' omit reference to typography, many rely on it to convey meaning.
1.2 Diagrams as a subject of inquiry

Typography has long been a subject of historical inquiry. Various systems for classifying type have been proposed and there is an extensive literature on legibility studies [5]. Psychologists have speculated for a number of years about the way we perceive pictures and various theories have been put forward [6]. The more particular problems of illustration have only recently become a subject of investigation, and some of this work will be introduced later. The study of symbols and signs in general is the concern of the subject known as 'semiotics' [7].

Diagrams, however, seem to have been somewhat neglected by researchers. Marcus (1977 p12) has observed that:

'Educational curricula rarely reflect this field of study and it emerges only sporadically as a subject of enquiry in journals of psychology, semiotic, art history and visible language.'

In comments preceding the section 'Scientific and mathematical diagrams' of the bibliography Graphics in text, Macdonald-Ross and Smith (1977 p30) state that:

'To develop [a] detailed understanding [of diagrams] we need historical studies, conceptual analysis, taxonomic proposals and evidence of usage: in short we need the kind of natural history which preceded the growth of all sciences. If there ever is to be a science of instruction it cannot leap into existence fully grown. Useful and interesting empirical tests are dependent on this ground-cleaning scholarship.'

They go on to note (ibid) that:

'working scientists have almost never conducted experiments on their own diagrams: they seem mostly to use diagrams without being aware of what they are doing.'

Goodman (1976 pl71) corroborates this when he says:

'...scientists and philosophers have on the whole taken diagrams for granted.'
This is remarkable, especially if, as Macdonald-Ross (1979 p223) asserts elsewhere:

'These specialized graphic forms have played an important part in the origin of scientific hypotheses.'

When proposing the subject of diagrams as a special field of study Marcus (op cit p20) comments that:

'As yet there is no primary locus for such investigations. It is a curious quirk of intellectual history that the semiotic meta-languages which attempt to diagram linguistic structure were never focused on diagrams themselves, the visual correlates of verbal meta-languages. It is quite likely that such a diagram-oriented meta-language would itself make use of diagrams.'

A review of the literature supports this general notion of a paucity of scholarship in this field. However there have been a few recent studies on diagrams, and these are considered in Chapter 2, together with some other work which has a bearing on the thesis presented here.

The aim of this present work will be outlined now.
The aim of the work reported in this dissertation is to provide a theoretical framework for dealing with diagrams which will be useful to information designers, teachers of graphic design, and researchers in visual communication. The work is approached from the point of view of a teacher of students of graphic design [8]. It must be made clear that it is primarily issues connected with the interpretation of diagrams which are dealt with here. Other very important topics, and here I have aesthetics particularly in mind, are not features of the present investigation.

Rarely do practitioners and teachers in graphic design have the time to stand back, as it were, from their subject and contemplate its nature. The work described here represents the result of such a rare opportunity. Necessarily, in a study such as this, the area of interest can only cover a small part of the concerns of the graphic designer. It should be said that the selected area of the diagram corresponds mainly to the author's own enthusiasms. The particular objectives of the work are to:

1. Propose a terminology for discussing diagrams.

2. Provide a scheme for analysing the structure of diagrams.

3. Identify the fundamental modes of graphic organization found in diagrams.

The first of these objectives is desirable for, as Marcus (op cit p12) has pointed out:

'The subject of diagrammatic visible language is a difficult one to investigate because awareness of diagrams as a distinct subject has made but quiet progress...[and] consequently there is no widely
used meta-language for discussing diagrams.'

An example of some of the difficulties of description which might arise may be gauged by considering the following examples.

I would suggest that one would not normally be disposed to use the term 'diagram' to refer to, say, a picture of a naked man, depicted in a manner which I shall describe as a 'realistic' for the time being. However, one's disposition might change if some labels were added and these were linked by means of connecting lines to various parts of the body shown in the picture. These labels could refer to the names of medical conditions and such a diagram might be used in a home medical book. See Figure 1-1. Readers may allow that this human figure is shown in a realistic, albeit stylized manner. One might even refer to it as a 'realistic diagram' [9]. The point I would like to argue is that the picture of the human figure is not itself a diagram. It becomes a diagram when we use the relations between the labels and the various parts of the pictured body to stand for other relations existing externally to the display. In the case of Figure 1-1 the relations represented are the links between certain ailments and particular parts of the anatomy. This correlation manifests itself as pain in a sufferer and is itself invisible. The thesis put forward here is that the observable connections shown in the diagram, between the labels and parts of the pictured body, may be thought of as a kind of graphic metaphor. The linking lines in Figure 1-1 stand for connections of a different nature — the associations we suppose are made mentally by the originator of the diagram, and later by its readers.

Now let us consider Figure 1-2 which shows a schematized representation of a person running. It is in fact a multiple exposure on a single photographic plate, producing a diagram called a 'chronophotograph'. It shows a man wearing a black velvet suit with white markings on the head, an arm, a leg and a foot, moving against a black background. We may observe both the position of one limb
Figure 1-1
From: The universal home doctor
London: Odhams
Frontispiece

DIAGNOSIS DIAGRAM: THE MALE ANATOMY
Letters indicate the centre of the areas where warning pains may occur.

Figure 1-2
A chronophotograph made in 1883 by Etienne-Jules Marey
relative to another in an individual stick man, and also
the relation of one stick man to others. The heights of
the different heel positions above the ground may be noted,
as may the pattern of their trajectory traced on the
plate. We take each occurrence of an arm or leg to be the
same arm or leg displaced in space, and therefore in time.

In this case the relations in the diagram have a more
direct correspondence with the relations they are used to
represent, both being spatial. Although Figure 1-2 uses a
more schematized depiction of a human figure than that used
in Figure 1-1, in terms of what is actually diagrammed, it
is in a sense more realistic. And yet, I would suggest
that at first glance one might well regard Figure 1-1 as
the most realistic diagram.

It is part of the work presented here to provide a more
precise scheme of terminology than is customarily used by
designers and design teachers. The proposed scheme is
aimed at avoiding the difficulties of description and
apparent contradictions of classification evident from the
comparison of the examples given above.

Not only would such a scheme be of value for teaching
purposes, but a more precise, agreed terminology should be
of value to practitioners when they discuss various
approaches to problems of diagramming. It would allow a
more exact specification of anticipated needs. The
discrimination permitted by a precise terminology is also
likely to be of value to those engaged in research into
various issues related to communication through diagrams.

The second objective, to provide a scheme for analysing the
structure of diagrams, helps to generate this precise
terminology. However, the scheme of analysis has been
devised primarily as a means of scrutinizing a selection of
specimen diagrams. This is done with a view to meeting the
third objective of identifying the fundamental modes of
graphic organization found in diagrams. In the final
chapter I have suggested how such a taxonomy of
organizational modes could be of use to the designer of diagrams.

In the next section of this present chapter the organization of the whole dissertation is described in outline.
This dissertation is divided into ten chapters. Each chapter is concluded with a short summary which includes any key terminology which has been introduced.

Following this first introductory chapter, Chapter 2 outlines some previous relevant work. Chapter 2 also includes a description of the methodology employed in arriving at the theoretical framework presented here.

Chapter 3 describes the method of diagram analysis used in the present work. In this method, what I call significant elements are the primary units of analysis.

The next three chapters are concerned with the possible sorts of relationship that can exist between significant elements and what they are taken to represent. These relationships rest on the possibility of there being what I have called a literal correspondence between what is depicted in a diagram, and what it is a diagram actually stands for. This is similar to the idea that some sorts of picture are more realistic than others and, as the validity of this concept has been challenged, it has been necessary to deal with this at some length.

Chapter 4 concerns theories of picturing and puts forward some of the arguments against the idea of there being such a thing as realism in pictures. Some counter arguments put forward by myself and others are given. My own position on this issue is outlined.

Chapter 5 describes the various sorts of relationship which can exist between significant elements and what they are taken to represent. I have termed these sorts of relationship the modes of correspondence.

It is argued that the less literal the mode of correspondence, the more a diagram makes use of a graphic
equivalent of metaphor. The operation of metaphor in diagrams is described in Chapter 6.

In this work a distinction is drawn between the extent to which a diagram may be said to be literal, and the degree of fidelity and detail used in the rendering of its elements. The various levels of image fidelity are designated the modes of depiction and this is the topic of Chapter 7.

The mode of correspondence and the mode of depiction are two variables available in the making of diagrams. They are related to a third important variable described in Chapter 8 called the mode of organization. This is concerned with the fundamental graphic possibilities available for representing relations. A principal part of the thesis presented here is that the modes of organization are actually quite restricted. Three candidates are proposed as being all that are available for certain important classes of diagram. It is argued that all diagrams in this class are made up of combinations of these limited modes of organization.

The relationship between the modes of correspondence, depiction and organization is exhibited in a taxonomic model presented in Chapter 9.

The auditing of diagrams is also described in this chapter. The method of analysis described in Chapter 3 is used as a basis. The descriptions of the audits of two specimen diagrams are offered as evidence of the existence of the modes of organization described in Chapter 8. Additional audits are given in Appendix B.

Chapter 10 summarizes the thesis and suggests that a knowledge of the concepts and arguments put forward here may be of value to the designer of diagrams.

Chapter 10 is followed by the Bibliography.
There are four appendices.

Appendix A gives the sources of the sample of diagrams collected as the raw material of this investigation.

Appendix B contains the additional diagram audits mentioned in connection with Chapter 9.

Appendix C lists all previous publications by the author. Of those published during the course of this present study only one is relevant to the topic of this dissertation. This paper is reproduced.

Appendix D contains the author's curriculum vitae. This has been included so that interested readers may gain an appreciation of the background from which this work has been approached.

Chapter 2 now follows and commences with a discussion on the definition of the term diagram.
Summary

There has been an increasing interest in 'information design' in some colleges of art and design, and there seem to be increasing employment opportunities for graphic designers skilled in this type of work.

Whilst typography, pictorial illustration, and sign systems have all been studied, little research work exists which is concerned with diagrams.

The case for 'ground clearing scholarship' was put forward and the particular objectives of this study were given. These are to propose a terminology for discussing diagrams, to provide a scheme for analysing the structure of diagrams, and to identify the fundamental modes of graphic organization found in diagrams.

The general organization of the dissertation into its ten chapters was given.
2 PREVIOUS STUDIES AND PRESENT METHODOLOGY

2.1 Definitions of 'diagram'

2.2 Previous studies

2.3 Present methodology

Summary
2.1 Definitions of 'diagram'

So far it has been assumed that the term 'diagram' is understood. But before proceeding we must decide how to recognise instances of the topic under investigation with a fair degree of accuracy. We must answer the question: What is a diagram?

Looking at the etymology of 'diagram' we see that it has Greek roots. Dia is a prefix meaning, 'through, throughout (of place and time); through the agency of' and gram is a suffix meaning, 'something written, a letter.' (Wyld nd)

Dia in this context presumably means one thing standing for another (through the agency of), and the suffix gram implies marks on a surface forming a static record.

Using this as a basis we shall consider some definitions. It should be said that those of Peirce and Maldonado use terminology from semiotics, the study of signs, which is introduced in Section 2.2 following. In order to make the quotations given here clearer I will briefly describe the meaning of some fundamental semiotic terminology. Signs are the most general category and these may be divided into icons, indices, and symbols. Very generally, icons are usually understood to resemble in some way what they stand for, portraits often being cited as examples. Indices direct one's attention to what they represent in the way a pointing finger does. Symbols take their meaning purely by means of a conventional code; that is users have some prior understanding as to what a symbol is supposed to mean. Sign, icon and index are the semiotic terms used in two of the definitions of 'diagram' which follow.

Maxwell (1910)

'...to mark out by lines, a figure drawn in such a manner that the geometrical relations between the
parts of the figure illustrate relations between other objects. They may be classed according to the manner in which they are intended to be used, and also according to the kind of analogy which we recognize between the diagram and the thing represented...'

Peirce (4.418)
'A diagram is a representamen [sign] which is predominantly an icon of relations and is aided to be so by conventions. Indices are also more or less used. It should be carried out upon a perfectly consistent system of representation, founded upon a simple and easily intelligible basic idea.

Funkhouser (1937 p365)
'This is a term used in a generic sense to include all of the various kinds of graphs, charts, lines and pictorial illustrations for the display and comparison of numerical data. It is usually not considered to include cartograms.

Chambers's Twentieth century dictionary (1959)
'...a figure of plan intended to explain rather than represent actual appearance: an outline figure or scheme: a curve symbolizing a set of facts: a record traced by an automatic indicator.'

Maldonado (1961 p49)
'Sub-class of the logogram. Visual language sign which is not based on iconic representation.'
A logogram is defined as: 'Visual language sign for a referent [that which is designated or denoted by a sign], without taking account of the speech sound dimension. Subclasses are: diagram and pictogram.'

Garland (1979 p16)
'Visual language sign having the primary purpose of denoting function and/or relationship.'
Potter (1980 p135)

'Diagrams are abstract, partial, energetic, concerned to establish or convey ideas and values directly, thus having an analytical or interpretive purpose. Usually have open conventions (excepting graphs and mathematical conventions), may be imprecise, or may be examining exact quantities, usually have a diagnostic function.'

It seems to me that the later definitions add little to that of Maxwell's, and indeed some appear to be contradictory (cf Peirce and Maldonado). I have found the concept put forward by Maxwell, of relations in the diagram illustrating relations between other objects, to be the most useful for distinguishing diagrams from other graphic forms. It is this characteristic, together with that of being marks on a surface forming a static record, which has been looked for when gathering the specimens used in the study reported here.

'Model' is a term closely associated with that of 'diagram'. 'Model' has many meanings, including that of being a three-dimensional representation, especially when the term is used to apply to a scale model. In the present context it is the meaning usually applied in science that is of interest. Here a model is a tool for experiment which may tell us what we do not already know - its performance under certain simulated conditions predicts what will happen when the actual conditions occur in the system the model emulates. Models may be physical objects or mathematical constructions manipulated in a computer. They may even be purely conceptual and sometimes they can be expressed graphically. Diagrams, however, are always graphical and explain or record for the future what is already known to the maker. Sometimes diagrams may perform like a models by revealing the unexpected, and models, when depicted graphically, can function like diagrams. In this situation models display function through exhibiting structure, or they may be used to show what they have previously revealed. In these cases the particular graphic
expression is sometimes regarded as the diagram while the model is taken to be the more general concept. Despite the fact that in everyday usage, even among scientists, the two terms may be used synonymously, the distinction described above provides a theoretical basis for introducing the term content model into this dissertation. The content model is the collection of objects shown in a diagram, as opposed to either the display which depicts them, or the meaning they may refer to. This distinction is elaborated in Chapter 3.

In the concluding chapter I offer my own formulation for the term 'diagram', based on the results of this investigation.

Having established here, in general terms, the character of the topic, it is now appropriate to consider previous work which is of relevance.
2.2 Previous work

As already mentioned in Chapter 1, the literature review carried out as part of this study confirmed that there is little reference material of a general nature currently available to students and practitioners of diagram design. Perhaps the publication best known to graphic designers is the *Graphis diagrams* book (Herdeg 1974). This is simply a compendium of attractive diagrams and makes no attempt at analysis. An earlier work with a similar approach is that of Lockwood (1969).

Bertin (1973) does give detailed analyses, but these are mainly concerned with cartographic material and particularly maps carrying statistical information. Monkhouse and Wilkinson (1971) are worthy of mention here as they give a comprehensive guide to the compilation and construction of maps and diagrams for students of cartography.

A conspectus of the diagram as an instrument of thought, from the standpoint of artists, is given by Albarn and Smith (1977). Gombrich (1982) has also dealt with issues related to present concerns in his essays on 'Mirror and map' (op cit pp172-214) and 'Image and code' (op cit 278-297).

There are also a number of earlier volumes, now out of print, of the 'how to do it' type concerned mainly, but not exclusively, with the presentation of statistics in diagrams. Notable amongst these is Brinton (1914) which contains examples with descriptions, and some judgements by the author as to the relative merits of different approaches. Another work in a similar vein is that of Karsten (1925).

There is also Modley (1937), Lutz (1949), and Modley and Lowenstein (1952). The chapter on 'Cheating with charts' in the latter volume (pp68-79) contains some useful
pointers on chart design, especially concerning the problems which can arise from the gratuitous use of three dimensions.

As to the historical development of statistical charts, there is the essay of Funkhouser (1937). A shorter account is given by Beniger and Robyn (1978), who have also tabulated chronologically the key innovations in quantitative graphics (Beniger and Robyn 1976).

Karsten (op cit pvii), mentioned previously, states that the general structure of his book Charts and graphs follows a philosophic rather than an encyclopedic arrangement:

'It therefore incidentally supports the author's theory of a system of natural evolution of charts, in accordance with which all chart-forms fall into line with simple origins and clear channels of growth. In the light of this theory there is no baffling heterogeneity, no confusion of purpose or principles in all the immense multitude of existing graphic forms. On the contrary that multitude resolves itself into a consistent, organic body of simple root-forms and logical combinations and developments. Not only can we allocate each form to its proper place in such a system, but we can often discover gaps in the system, and bring to light forms which while not yet in use have reason to be.'

Karsten goes onto describe three simple types of chart from which all others are developed. These are those adapted to show:

- space relations (maps and diagrams)
- topical relations (classification-charts)
- relations in motion (route-charts)

In some respects Karsten's approach is similar in spirit to the approach used here. The modes of interpretation I have proposed, while somewhat more fundamental than Karsten's 'root-forms', are also intended to reveal that all diagrams have 'simple origins'.

2/6
Another taxonomy of diagram types is that of Macdonald-Ross (1977a p70) who proposes that a more sophisticated classification could be developed from his simple list of four basic purposes:

'iconic purpose'
'data display purpose'
'explanatory purpose' and
'operational purpose'.

Apart from the fact that these categories do not seem to be all of quite the same kind, there are other reasons why this approach has not been adopted here, as will be clear from the arguments put forward later.

In a different vein, Meredith (1961 pp149-170) gives brief descriptive analyses of ten different diagrams in the last chapter of his book Learning, remembering and knowing. This chapter is entitled 'Graphic language of organization' and the analyses are given so that,

'Whether or not the reader is interested in any of the subjects represented in the ten examples given... he can still learn something from each concerning the endless flexibility and power of graphic expression.' (op cit p150)

The inclusion of diagrams in textbooks as examples of how graphics may be used, rather than as illustrations of what the diagrams represent, is exceptional outside the sort of compendia already mentioned.

Such an exception is The graphic representation of models in linguistic theory (Stewart (1976). This book is devoted entirely to consideration of the diagrams of the specialist discipline of the author. Much in this book is relevant to the portrayal of concepts unconnected with linguistics, and references to Stewart's work are made in this dissertation. Some valuable insights have also been drawn from the article 'The diagram is the message' (Shera and Rawski 1968), which is written from the standpoint of Librarianship.

Returning to statistics, an important innovation in the
diagramming of quantities for popular consumption is the International System Of Typographic Picture Education (ISOTYPE) devised by Otto Neurath (1936). A fundamental concept of this system is the use of multiples of standard-sized pictograms to represent variations of quantity [1]. This contrasts with earlier attempts to popularize statistics which used depictions of varying size. A useful review of Neurath's work and its influence is given by Kinross (1981).

At about the same period that Neurath was developing his ISOTYPE system in Vienna, Henry Beck in England was devising the now justly famous London Underground Diagram. Beck realised that users of the railway system were mainly interested in the sequence and interconnections of stations, and so introduced a topological diagram to replace the original geographical maps. This innovation and its graphic style have been emulated countless times, all over the world, for various transport systems. Garland (1969) has done much to bring to the attention of graphic designers the value of Beck's original work.

It is interesting to note that these two major developments in the graphic design of diagrams for public use were made by men who had had no formal art school training, and who were not what we would call today graphic designers. Of course 'graphic design' is a term which has only been coined recently, replacing the former term 'commercial art' [2]. As mentioned in Chapter 1, the idea that graphic designers might be legitimately concerned with the structuring of factual information is more recent still.

A further indication of the increasing general interest in this area of design was the welcome appearance in 1979 of the Information Design Journal. This offered a much needed forum for the exchange of views and research findings by those interested in the less frivolous aspects of graphics. A number of papers from this journal are cited here.

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[1] Macdonald-Ross (1977b p36) has noted that this basic concept was exhibited first by Brinton (op cit p39). However it was Neurath and his team who attempted to develop this idea into a standardised and systematic method.

[2] The term 'graphic design' is attributed to the late Professor Misha Black of the Royal College of Art.
Another area of study, which should be mentioned, is the testing of subjects' responses to diagrammatic material. This work has been carried out mainly by psychologists with a view to establishing which format, if any, is preferable for particular uses. Some of these studies have been reviewed by Macdonald-Ross (1978). Notable in this field is the work of Patricia Wright, who has devised some elegant tests to discover the relative efficiency of prose, tables and flow charts for presenting information (Wright and Reid 1973).

It is now appropriate to briefly review work of a more theoretical nature.

Semiotics is concerned with the study of 'signs' and A theory of semiotics has been put forward by Eco (1977). A shorter, more tractable introductory text is that of Guiraud (1975), called Semiology.

The terms 'semiology' and 'semiotics' (or 'semiotic') may be regarded as synonymous. The two words arise from the separate and virtually simultaneous conception of this study by the Swiss linguistic scholar Ferdinand de Saussure, who used the word semiology, and the American logician, Charles Sanders Peirce, who used the word semiotics.

'Saussure emphasizes the social function of the sign, Peirce its logical function. But the two aspects are closely correlated and today the words semiology and semiotics refer to the same discipline; Europeans using the former term, Anglo-Saxons the latter.' (Guiraud op cit p2)

For the semiotician, a sign is an all-embracing category which can be anything which stands for anything else in some respect. Thus a sign may be the call of a street vendor, a style of dress, a gesture, the spoken word, or a portrait. Unfortunately the term 'sign' is generally used in a more restricted sense by graphic designers and it sometimes even means the board upon which the semioticians'
sign is placed. Because of its currency in graphic design I shall try to avoid using the term 'sign' except where necessary, in which case its context should make its meaning clear. The problem of terminology is confounded by the fact that graphic designers often use the terms 'sign' and 'symbol' synonymously, whereas for the semiotician, the symbol is a special sub-set of the general category of sign [3].

On the whole semioticians have not paid much attention to graphic signs and semiotics is often regarded as a branch of linguistics. Bertin (op cit), whose *Semiologie graphique* has already been mentioned, is one notable exception.

Certain aspects of semiotic analysis will play a key role in the present study and these will be explained at the time of their introduction into the text.

Now a few words should be said about some recent research into graphic illustration and diagramming.

Knowlton's (1966) paper 'On the definition of "picture"' raises a number of theoretical issues relevant to the thesis presented here, and these will be taken up in detail in Chapter 6 on 'Metaphor in diagrams'. Other issues relating to the perception of pictures from a psychological standpoint are introduced in Chapter 4 on 'Problems concerning theories of picturing'.

Twyman (1979) has given us 'A schema for the study of graphic language', shown here as Figure 2-1. This schema, 'seeks to identify the principal options open to anyone using graphic language. It takes the form of a matrix. The top headings of this matrix define the major configurations or ways of organizing graphic language. Linearity is a characteristic of speech that is almost impossible to find equivalents for in graphic language, but the configurations
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<th>Linear interrupted</th>
<th>Linear branching</th>
<th>Matrix</th>
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begin with pure linearity to the left and end with non-linearity to the right. In between these two extremes are the conventional configurations of graphic language (linear interrupted - the normal graphic approximation to the linearity of speech - then lists, branching structures and matrices). The side headings define the principal modes of symbolization: words (including numerals), pictures and words combined, pictures on their own, and schematic images.' (Twyman 1982 pp8-9)

Various examples are given by Twyman (1979) which fill some of the boxes of the matrix and help to make clear the concept. The main area of concern in the present work is of course the row labelled 'schematic'. It is interesting to note that Twyman (1979 p121) says,

'...it is more difficult to establish a distinction between pictorial and schematic modes than between other categories on this axis; for this reason the division between them is indicated by a dotted line.'

The theoretical framework proposed as part of the present thesis attempts to explain the nature of this classificatory difficulty.

Other recent work on graphic illustration includes Goldsmith's (1978) Analysis of the elements affecting comprehensibility of illustrations intended as supportive to text and Ashwin's (1979) classification of 'The ingredients of style in contemporary illustration'. Both of these studies have been drawn on during the course of my investigation, and this is reported at appropriate points in the text.

Harrison's (1964) work ...towards a vocabulary and syntax for the pictorial code...is introduced in the next chapter on analysing diagrams, as an example of a contrasting approach.

Finally the work of Hardin (1981) must be introduced, as this is the only previous study found which is directly concerned with the graphical characteristics of diagrams.
Hardin (op cit p7) herself states that,
'No report describing a formal investigation of the relationship between design traits and meaning in diagrams has appeared.'

Hardin sets out to establish whether certain variables in messages describing relationships have an effect on design traits in diagrams produced from those messages. College students, relatively untrained in design, were provided with a selection of differently shaped diagramming elements and base boards on which to arrange them. They were then asked to make diagrams to represent certain messages given to them in writing. The message, which described the relationship between imaginary entities, varied in terms of such things as explicitness, complexity, and narrative style. The resulting diagrams were rated by trained scorers in terms of the extent to which the design traits of linearity, order, continuity, and geometry of forms were present. Hardin (op cit p106) reports that,
'The results strongly supported by contention that linearity, order, and continuities would reflect the explicitness or open endedness of diagrammatic messages. To a lesser extent, diagram complexity and narrative styles of statement also influenced linearity, order and continuities; however, they did not show the repeated and persuasive influence on all three design traits associated with the explicitness variable.'

If I might paraphrase this, it would seem that what was predicted, and what was mainly evident from the tests, was that the more direct the message, the more directness was judged to be present in the resulting diagrams.

When describing her experiments, Hardin (op cit p22) states that,
'Prohibition of the use of representational images in diagrams was an essential condition of the diagramming task.'

She (ibid) argues that,
'Since the use of elements of design structure for communication was the focus of the research reported
here, the use of representational images might
distract diagramers from the spatial communication
imperative.'

This prohibition of the representational is an interesting
condition if we take 'representational' to mean resembling
something. I shall argue that there is a sense in which
all diagrams resemble something, even if it is at a very
high level of generality, and indeed it is this resemblance
that gives them their meaning.

The methodology employed in the work reported in the
present dissertation is described next.
2.3 Present methodology

If the nature, use, and history of diagrams as a subject of inquiry needs a name then I propose that

diagrammatics

almost suggests itself. The aspect of diagrammatics dealt with in this dissertation is the nature of diagrams; the questions it seeks to answer are to do with how diagrams take their meaning and with the sorts of things that different classes of diagram can be used to express. The work is then, in essence, a descriptive analysis of diagrams in terms of what I shall call the

modes

by which they may be interpreted by their readers.

Assuming that description is a necessary prelude to a more complete understanding, it is hoped that aspects of this analysis will provide designers with pointers to the production of effective diagrams.

Little exists in the way of research tradition in graphic design and this present investigation is necessarily propaedeutic in nature. There are no well established methods for dealing with diagrams from the point of view taken in this work; however, one important taxonomy is borrowed from semiotics and an analytical technique has been adapted from a concept used by Goldsmith (op cit). This taxonomy and analytical technique are described in detail in the next chapter. First a more general description of the approach used here will be given.

Maxwell's (op cit) definition of 'diagram', given in Section 2.1, was adopted. It was also decided to direct the investigation towards diagrams designed for a general readership. That is, the scope of the inquiry would not extend to diagrams used by specialists, such as, say, computer scientists, biologists, or physicists. However, it was not intended to exclude diagrams dealing with specialist subjects. Rather the intention was that most of the diagrams considered would be of the character found in
popular encyclopedic works, designed for the ordinary adult reader who has reached an average educational level (that is literate, but not necessarily having had access to higher education). This covers a wide audience, and one, it may be assumed, that most graphic designers design for most of the time. Implicit in this assumption is the idea that we are operating within a modern western European culture. However, one or two specialist diagrams have been examined during the course of this work and a number are given as examples in the text. Indeed, if the arguments put forward here are accepted, at a fundamental level of interpretation there is no distinction to be made between specialist and non-specialist diagrams. This is the level at which the invented conventions of a particular discipline play no necessary part. Also, whilst the emphasis has been on present-day diagrams, one or two specimens of an historic nature have been included amongst those examined.

The raw material for the inquiry was a large number of specimen diagrams which I selected from various, mainly popular, sources. These sources are listed in Appendix A. Over 550 specimens were collected for the original sample. Consideration was given to the idea of adopting some systematic approach for the collection of specimens. Finally, however, the collection was done more or less randomly, Maxwell's definition being applied fairly liberally.

The first approach was to try to organize the sample into groups of specimens with similar structural characteristics. The specimens within each group, it was assumed, would therefore be interpreted by readers in a fundamentally similar way. This pilot scheme was successful up to a point. The following broad categories emerged. Diagrams which display:

groupings of, and within, objects
(eg, zoned maps, rock strata diagrams)
groupings of an abstract nature
(eg, tables, Venn diagrams)

linkages and sequences in actual systems
(eg, wiring diagrams, route diagrams)

linkages and sequences of an abstract nature
(eg, flow charts, family trees)

relative magnitudes of objects
(eg, size-of-planets diagram, growth rate chart)

relative magnitudes of abstract data
(eg, line graphs, histograms)

segmented movement or development
(eg, frame by frame sequences, superimposed sequences)

loci
(eg, flight pattern of birds, passes in football)

hidden detail
(eg, cut-away technical illustrations, ghosted drawings)

distributions
(eg, location maps)

configurations
(eg, naming of parts diagrams)

There were also two additional categories: one for those specimens which finally were judged not to be diagrams, and one for those which may be described as allegorical tableaux. These were taken mainly from Heniger's (1977) book, The cosmographical glass - Renaissance diagrams of the universe [4].

The principal difficulty with this method of categorization
is that clear-cut distinctions are often impossible to make. Whilst in some cases a particular characteristic may predominate, in others, several characteristics may seem to be equally prevalent. Hence a diagram can apparently belong to several categories simultaneously. It seemed that what was required was a process of classification which operated on some kind of 'warm logic' as proposed by de Bono (1979). Such a system would use flagpoles rather than boxes. A phenomenon may be nearer one flagpole rather than another, and hence sharp categorization is avoided. During the course of this investigation, various classificatory models were devised based on the warm logic idea, using flagpoles devised from the categories thrown up during the pilot scheme. The model shown in Figure 2-2 is one example. The classification of a diagram then became a question of locating a point in the space defined by the model such that the distance from the 'flagpoles' corresponded to the extent to which various classifying characteristics were judged to be present in the specimen.

This process also proved to be quite difficult in some cases. It did not reveal much about the nature of diagrams and how we may ascribe meaning to them. I judged that these difficulties arose from the fact that diagrams are largely composites of various graphic elements. Within a single diagram the various elements may have different characteristics of interpretation, and the meaning of a diagram is based on the interaction we see between these various elements. Consequently, attempts to give a single classification to a whole diagram in terms of the way we may interpret it are untenable. What is needed is a method of analysing diagrams into their constituents, together with some appropriate scheme for the classification of the resulting elements. Such a scheme should account for the apparent diversity of diagrammatic types and hence reveal the fundamental interpretive modes available for making diagrams. These modes will, in a sense, represent the principal variables in diagram design.

The rest of this dissertation is essentially a description
of, and justification for, the theoretical framework and associated method of analysis which is a major outcome of the investigation. This framework and method of analysis evolved through a process of matching various schemes against a selection from the sample diagrams. The presentation of this scheme as a diagram appears in Chapter 9. The 'Audits of specimen diagrams' also given in Chapter 9, are offered as a test of the validity of the scheme.

In the next chapter the method of analysis is introduced.
Various definitions for the term 'diagram' were considered. The working definition adopted for the investigation was outlined and essentially amounted to: marks on a surface forming a static record, where the relations in the diagram are used to illustrate relations between other objects.

Previous work relevant to the present inquiry was mentioned. This included diagram compendia, 'How to do it' books on statistical charts, the ISOTYPE method, the design of the London Underground diagram, semiotics, diagram testing by psychologists, and some recent studies on graphic illustration. The one formal inquiry into diagrammatic form and meaning, revealed by the literature search associated with this study, was also described.

The term diagrammatics was introduced as almost suggesting itself as the name of the general subject area into which this present introductory project falls.

The lack of a research tradition in graphic design was mentioned and the methodology devised for this present study was given. This was based on a pilot scheme in which a large, random collection of diagrams was sorted into families. This proved to be difficult because frequently specimens seemed to belong to several families simultaneously. It was proposed that a system of analysis was needed which would allow the various constituents of diagrams to be classified individually. It was reported that the rest of the dissertation was concerned with the description of this process of analysis and classification, together with the associated theoretical framework.
3.1 A linguistic approach

3.2 Significant elements in diagrams

3.3 Parsing diagrams

3.4 Noun and Verb space

3.5 Syntactics, semantics, and pragmatics

Summary

From: Daily Mail 16 May 1961
3.1 A linguistic approach

The work described in this dissertation is essentially taxonomic in character. Now de Bono (1976 p109) tells us that,

'It is easy enough to sneer at the classification method on the grounds that putting labels on something creates no knowledge about it. Nevertheless the method does have value because it carves out definite areas of attention by creating labelled concepts that can be attended to.

I concur with this view. In order to attend to diagrams we need some labels and since this is a relatively unexplored subject there are few well established terms available to us. Indeed one of the purposes of this study is to provide a metalanguage with which practitioners and scholars may discuss diagrams. I have tried to avoid the needless coining of new words, but have, where it seemed appropriate, adopted or extended the application of terms used in semiotics and linguistics. Of course the use of a previously established terminology implies the adoption of the associated concepts, so the relevance of linguistics to present concerns needs to be outlined. This chapter will therefore explore some correspondences between words and pictures. Also the idea of there being an equivalence to sentential grammar applicable to diagrams will be introduced.

There do seem to be some similarities between speech and diagrams as others have observed:

'The sense in which language is most expressive and least arbitrary, according to Roman Jakobson, is in its status as an elaborate diagram.' (Bolinger 1968 p241).

Lévi Strauss (1972 p62) has not only wondered,

'Whether the different aspects of social life (including art and religion) cannot only be studied by the methods of, and with the help of concepts similar to those employed in linguistics, but also whether they do not constitute phenomenon whose
inmost nature is the same as that of language."

Whilst certain parallels between the grammatical structure of language and the graphical structure of diagrams may be useful, particularly for providing descriptive terms, care must be taken not to push too far such similarities as there may be.

A system of picture analysis which closely follows the linguistic model has been proposed by Harrison (1964), who calls the study of pictorial communication 'pictics'. This system includes the graphical equivalents of phonemes, morphemes, etc, with fundamental units of dots and lines [1]. He points out (op cit pl0) that 'levels of structure' are a characteristic of most communication codes.

Typically certain elements at one level join together to form a unit, which in turn becomes an element at the next level. Harrison (op cit pp10-11) suggests that:

'In a fully formalized system of pictic analysis we might expect to have a well-explicated terminology to distinguish various levels of structure. We might, for instance, speak of the following:

a. Pict: a basic pictorial element, such as a dot, a line or an uninterrupted segment of a line.

b. Picteme: a group of interchangeable picts; a bundle of distinctive features.

c. Pictomorph: the minimal meaning unit; a pattern of one or more pictemes which can't be broken up without destroying or drastically altering the meaning.

d. Pictophrase: groups of pictomorphs.

e. Picture: one or more pictophrases, set off as in a frame.

f. Picture layout: one or more pictures in a temporal context.
g. Scene: the next highest level, a picture sequence of some duration but usually limited to one location.

h. Production: the next highest level; it is "framed" by other activities not planned by the communicator.

i. Above this level we might speak of the sequel or the series.'

Harrison (op cit) restricts his attention to picts and pictomorphs, which he uses to contrast variants of a standard human face. These are used to identify meaningful facial expressions by testing subjects responses to them.

Figure 3-1 shows some of the faces, arranged and labelled according to the outcome of the testing. Each face represents a pictomorph while each feature is a pict. Whilst this terminology may be useful in the restricted application described by Harrison, there are difficulties in following too slavishly the methods of linguistics when dealing with graphic communication more generally. One such difficulty is the lack, in pictures, of a direct equivalence in terms of structural levels. In one pictorial context a dot or line may represent a complete object and in another it may be merely a more or less inconsequential constituent of some greater whole. For example a tick in one picture may be highly significant, representing a bird in the distant sky, and in another an identical mark may be one of a series of such marks portraying the texture of some surface. In the latter case the presence or absence of the single mark will have virtually no effect on the interpretation of the picture as the tick is not seen as a separate individual, while in the former case it is, and is consequently essential. One consequence of this is that there is no single fundamental set of identifiable elements which can be articulated into any picture.
Figure 3-1
From: Harrison (1964 p136)

Face 21 (neutral)

Face 25 (Annoyance)
Face 06 (Alarm)
Face 26 (Disappointment)

Face 30* (Anger)

Face 15 (Rage)

Face 11 (Dismay)

Face 10 (Glare)
While we cannot take writing to be exactly equivalent to speaking, it is the graphic correlate of speech, and we can treat it as equivalent for present purposes.

This comparison was used for a different, though not unrelated, purpose in Gardner, Howard and Perkins (1974 p31).

Vaugelas was a French grammarian of the seventeenth century who was an authority on the best usage of the language.

As Eco (1976 p215) puts it, 'iconic figure do not correspond to linguistic phonemes because they do not have positional and oppositional value...[they] can sometimes assume contextual meanings...but they are not organised into a system of rigid differences.'

The following illustration may help to clarify Eco's point. It will be understood that 'oo' has strictly regulated uses in written English, corresponding to a limited range of phonemes [2]. However, in a pictorial system it may serve an almost unlimited range of representational functions and operate at various levels of structure. Little Orphan Annie's eyes, shown in Figure 3-2 is just one such example [3].

Other objections have also been raised to following linguistic models too closely when analysing pictures (cf Barnard and Marcel 1978 p28, Goldsmith 1978 p104). Nevertheless one cannot help being struck by the apparent similarities between the nature of certain pictorial phenomena and speech. Frequently commentators use terminology normally applied to language when describing pictures and the notion of there being a pictorial grammar is common. For example, Funkhouser (1937 p320) tells us that, 'Cheysson goes on to say that everybody tries to use the [graphic] method but that nowhere is there the same tone nor the same accent. However at bottom, it is the same language which awaits its "grammar and its Vaugelas".'[4]

So, whilst it seems fruitless to look for the graphic equivalents of phonemes, I believe there are compelling reasons for considering the use of higher levels of linguistic classification when dealing with pictures, especially those we tend to call diagrams. Before pursuing this idea we need to explore more the relation between words and pictures.

For Wittgenstein (1961) language is made up of propositions
which must have 'logical structure'. George (1964 p114) has pointed out that it has sometimes been said of Wittgenstein's work that,

'his notion of logical structure was really based on the idea of literal visual relationships, so that one object to the left of another, or one taller or shorter than another could somehow fit every type of assertion: in other words that all statements that are empirical and claimed to assert something about the world refer to relationships that are envisageable in spatial terms.'

This is of relevance here as diagrams are primarily pictures of spatial relations, and the present enterprise is in part an attempt to explain diagrams in terms of sentential grammar. Wittgenstein is moving in the opposite direction when asserting that language is quite literally pictorial in character. Despite the fact that sentences do not look like pictures, he thought that if they are to have any meaning they must be capable of being decomposed into elementary sentences which really are pictures. These consist purely of names which correlate with objects, and the arrangement of the names mirrors the arrangement of the objects. Unfortunately Wittgenstein does not give us any examples of this process of decomposition.

The 'picture theory of meaning', as it is known, is contained in Wittgenstein's (1961) Tractatus. This theory underwent revisions in his later work, of which the Philosophical Investigations (1953) is the principal publication. Wittgenstein came to believe that meaning was determined by use and he compared the rule-bound nature of language to that of games. Some commentators take this to be a rejection of the earlier ideas and speak of 'the two philosophies of Wittgenstein' (cf Magee 1982 pp77-93). However Kenny (1973 p226), who gives a useful review of Wittgenstein's work, quotes various passages from the later writing which he says,

'seem to suggest that the picture theory needs supplementing, rather than that it is false; that the theory of meaning as use is a complement rather
than a rival to the picture theory.'

Moving from the idea of propositions as pictures we should now consider the picturing of propositions. Whether or not Wittgenstein's notion of logical structure can be true for all propositions, something of the sort would seem to be true for the propositions expressed in Peirce's 'existential graphs'. Existential graphs are essentially an extension of Venn's (1880) improvement on Euler's use of circles to express syllogistic propositions. Euler's (Brewster and Griscom 1833) diagrams are shown in Figure 3-3. Using the techniques of formal logic Peirce (4.355) demonstrates that the validity of a syllogism and the enclosing property of the Eulerian diagram arise from a common principle; that is that,

'They are analogous phenomena neither of which is, properly speaking, the cause or principle of the other.'

It may be of interest here to note Peirce's (4.355) views on the psychological aspects of this system of representation as it connects reasoning and spatial intuition.

'Lange [5] is of the opinion that all reasoning proceeds by the observation of imaginary Euler's diagrams or of something closely similar; and I for my part share his opinion so far as to admit that an imaginary observation is the most essential part of reasoning.'

Venn (op cit) extends the range of propositions which can be expressed in Euler's diagrams by introducing the following improvements. First, all the possible parts into which a set of terms can divide its universe are exhibited. Then regions representing parts which do not exist are shaded to show their exclusion.

Peirce (4,357) replaces Venn's shading with a system of notation, where the character '0' is placed in an excluded region. He extends the system still further by the use
Figure 3-3
From: Brewster and Griscom (1833)

Affirmative universal. | Negative universal
---|---
![Diagram](image)

**Every A is B.**

**Some A is B.**

**No A is B.**

**Some A is not B.**
of 'X', which is placed in a compartment to signify that something of the corresponding description does occur (4.359). Peirce removes other 'imperfections' in Euler's scheme, thus allowing expression of alternate states of affairs and the introduction of qualitative premisses (4.360-366). Alternate states of affairs are shown by lines connecting X's or O's; that is, assertions of existence or non-existence (see Figure 3-4). 'Minimal multitudes' are expressed in the manner shown in Figure 3-5 which says there are at least four A's.

Peirce (4.365) invites us to consider the premisses:

'Some S is not M
Some M is P
No N is P
Some M is N'

Using his extension of Euler's diagrams, these may be exhibited as shown in Figure 3-6. We should be able to conclude from this that,

'Some S is other than and other than something other than some P.'

This may be quite difficult for those unfamiliar with syllogistic reasoning. In my view Peirce's inclusion of alternate possibilities in single diagrams does not enhance their tractability.

In discussing the value of this system of graphs Peirce (4.368) tells us that,

'Its beauty...and its other merits...spring from its being veridically iconic, naturally analogous to the thing represented, and not a creation of convention. It represents logic because it is governed by the same law.'

This gives some insight into Peirce's use of the term iconic which clearly encompasses more than, or something other than, the usual kind of resemblance associated with, say, portraits, which are frequently cited as examples of iconism (cf Morris 1938 p24). Iconism here seems to be concerned with similarity based on something we might well call logical structure.
At this point it would seem appropriate to make a few comments on the relation between thought, language and spatial intuition.

The relations between language and thought are debated by philosophers and psychologists, particularly with regard to their development in children. Some would hold that mastery of the linguistic expression of a concept is sufficient cause for it to be learned, while others hold that cognitive abilities develop separately from language acquisition. It should be noted here that one of the principal tests devised to assess cognitive development in young children is the 'conservation experiment'[6]. This experiment takes various forms, but all have the single aim of testing a child's ability to recognise an equality of, say, volume or area following some spatial reorganisation performed before the subject - for example pouring a liquid from a tall thin glass into a short fat one. Children who have not reached the developmental stage of a 'conserver' are supposed to believe that the amount of water changes.

The important point is that the experiment is essentially spatial in character and is held to demonstrate cognitive ability. In particular Piaget (1952), who devised the original experiment, regards the concept of conservation as fundamental to forming a framework of numerical reasoning.

Now, with regard to the relations between spatial and linguistic ability and such questions as whether one is a requirement of the other, the following observation of Shephard's (1975 p116) is of interest. It is contained within a paper dealing with experiments which attempt to show the nature of our internal representations of three dimensional objects.

'The fact that binary spatial gestures (such as a flipping of the hands from palms up to palms down, or a motion of the hand from one side to the other side) often accompany linguistic shifts (such as a switch from the affirmative to the negative, or from an "either" phrase to an "or" phrase) hints that
there may just be, at the deepest level of representation a rather direct correspondence between grammatical and spatial intuition.'

Also, Gregory (1970) has suggested that there may be a 'grammar of vision' and that the grammar of language 'has its roots in the brain's rules for ordering retinal patterns in terms of objects'.

At the surface level, pictures and paragraphs look very different but the suggestions of Wittgenstein, Shephard, et al quoted here encourage speculation about possible correspondences between the 'deep structures' of our language competence and spatial understanding [7]. However, such speculation is not the purpose of this dissertation, but the possible existence of such similarities at the 'deepest level' leads one to look for resemblances nearer the surface. The extent to which echoes of the syntax of ordinary speech may be said to be present in the graphic structure of diagrams is considered next.

[7] 'Surface' and 'deep structure' are terms used by Chomsky (1976) in his analysis of language, which supposes that speakers have rules for combining a limited set of fundamental components of speech at some deep, underlying level. These 'deep structures' are converted into our rich, diverse everyday speech, or 'surface structures', by transformational rules.
In his analysis of ten diagrams, already introduced here in Chapter 2, Meredith (1961 p149) observes that,

'One of the factors which makes graphic organization so powerful is that it can draw simultaneously on a number of different codes and so achieve great economy of expression.'

The significant elements of a diagram, then, are not necessarily homogeneous in the same way that the elements of a written text are, or the spatiality of a perspective landscape is. Let us look at these in more detail.

Written texts are continuous streams of the same, limited set of characters, combined in a conventionally determined manner. It is true that on a printed page in particular we may use space, such as indentions or gaps between lines, to organize a text into groups, or feature different type styles as cueing devices to emphasise differences of content [8]. In this respect the use of certain modern typographic techniques has narrowed the gap between diagrams and the texts of the early printing period. These are characterized by the almost unrelieved visual constancy of their chains of words. Nevertheless, even with typographic cueing, the meaning of a text is principally determined by the one-dimensional sequence of words and sentences which is a feature of the primarily 'acoustical' nature of writing [9]. If this is not the case, and other organizing principles come into play, such as those found in tables, then, by the definition used in this dissertation, we would have a diagram.

The perspective landscape is homogeneous in that it portrays a single unbroken space at a single moment in time.

This may also be true of certain specimens which are near the borderline of the territory encompassed by the term...
'diagram'. However it seems that more than one space and more than one time can be portrayed in a single diagram. Or, to put it another way, the significant elements of a diagram do not seem necessarily to occupy the same space/time continuum, an argument which will be more fully developed later. Some elements may be highly conventionalized and function as symbols, such as words; the function of others seems to be strongly determined by what they represent, as is usually understood to be the case with iconic pictures. Others, still yet, seem to operate more like visual metaphors. Some diagrams, then, cannot simply be classed as icons or symbols. A single specimen may have parts which function through resemblance and others which do not.

This heterogeneity possibly accounts not only for the powerfullness of diagrams noted by Meredith, but the fascination they excite in many people and the fact that they do not yield readily to any simple analysis. Notwithstanding this difficulty, it is the purpose of this dissertation to propose a method of analysis which sheds some light on the problem of how it is that diagrams take their meaning.

So far I have used the term significant element in relation to diagrams without explanation. A significant element is the primary unit of analysis in the scheme to be proposed here. As already indicated I take the view that there seems to be little profit in using such items as an individual dot or line as a unit of analysis. If we are going to use linguistics as a model, then what is needed for present purposes is not the pictorial equivalent of a phoneme or morpheme but something closer to a noun phrase, such as might be exemplified in writing by 'the cricket bat'. However it need not represent some known object in the real world; it could be simply 'a tapered green line'.

A significant element is, then, literally any single graphic element in a diagram which signifies something or which at least is capable of having some meaning. In this

3/13
strict sense the term means more than in everyday speech, where it might normally be taken to mean anything important or outstanding. Significant elements have what Goldsmith (1978 p115) has termed 'unity' which refers to,

'...any area in a picture which might be recognised as have a separate identity, even if the identity is not known. The degree of "separateness" is obviously going to vary with the level of discussion appropriate to the intention of the picture: for example, in a landscape the single image might be a "cow", while in a portrait it might be "eye" or even "pupil". [10]

This notion of unity may seem somewhat imprecise and open to question as expressed above, since it is dependent on the 'intention of the picture'. There are indeed some difficulties of interpretation which will be encountered later, but it will be shown that the concept has practical value. I would suggest that for present needs the citing of a few examples will be sufficient preparation for a number of referees to achieve an acceptable measure of agreement as to which are the significant elements across a range of specimens. In any case the degree of precision for any analysis depends on its purpose and it will be seen that the lack of exact agreement between, say, two referees as to the elements of a particular diagram is not necessarily prejudicial to establishing the validity of the arguments which will be presented. If any analysis is going to be possible at all it seems that it must start at a 'noun phrase' level, otherwise we are forced down to the meaningless level of dots and lines or else up to the level where all we can say is 'here is a diagram'.

Before proceeding with some examples, Goldsmith's notion of unity needs to be discussed a little more. Implicit in her definition is a rejection of the 'meaning theory' of perception which is characterized by Köhler (1930 p55) as follows:

'"Objects" cannot exist for us before sensory experience has become imbued with meaning.'
Whilst not denying 'that objective experience is imbued with acquired meaning in many respects' Köhler (op cit p79 ff), like Goldsmith, rejects the link between meaning and existence as necessary for perception. Köhler is one of the founders of gestalt psychology [11].

'We may even say that in gestalt analysis we find genuine "parts" of the field as segregated wholes and groups, and in these wholes or groups, their genuine "parts" again as subordinate wholes and members...' (Köhler op cit p140)

According to gestalttheorie then, scenes will tend to 'segregate' themselves into 'wholes' and such wholes have the quality of 'solidity' as compared with their backgrounds which in contrast have a 'looseness'. In this connection the terms 'figure' and 'ground' are used (Köhler 1930 p169). Perceptual grouping of figures is predictable according to basic principles, called by Wertheimer (1923), 'similarity' and 'proximity'. These are the observable tendencies of like to band with like and objects situated close together to assume a collective character (see Figures 3-7 and 3-8). Gestaltists would claim that these tendencies are the consequence of dynamic forces operating in the parts of our brains which deal with sensory data. It is not necessary to give any detail of this explanation here but it should be said that psychologists of other schools discount this theory (cf Gregory 1971). However, there is no doubt that the gestaltists have identified several principles of visual organization which are of great value to the psychology of perception, whatever later explanations of the phenomena may emerge.

In so far as objects can have an identity before having a meaning, Goldsmith (op cit p121) identifies with the gestaltists as I do. She suggests that,

'...in some circumstances a mark on a surface could be generally accepted by all observers as one image rather than a group of images: a single circle on a sheet of white paper for instance, or even an ink blot, provided that it presented no incidental
spatter marks. In such a situation, I would argue, unity could be perceived without identification.'

We will now consider the specimen diagram shown in Figure 3-9 and identify some of its significant elements. It is taken from a sales brochure and the accompanying text makes it clear that the diagram depicts the history of the Miyano company in terms of its product development. The firm was established in 1929 to manufacture hand files, then, after World War 2, it started producing spark wheels for cigarette lighters. This led to the design in 1948 of an automatic lathe to reduce production time. This lathe in turn led to the development of various lines of automatic machines which Miyano supply to the machine tool industry.

The diagram makes use of a variety of codes which interact in a quite complex manner and this therefore makes it quite suitable as a subject for describing the analytic process proposed in this dissertation.

The branching flow lines are a dominant set of elements, and immediately we see the difficulty alluded to earlier when introducing Goldsmith's (op cit) notion of unity. Do we perceive a tree or a collection of branches? Following Goldsmith we must consider 'the level of discussion appropriate to the intention of the picture' and note that there appear to be five main branches, distinguished by their labelling at the top of the diagram. We ought then to judge these as separate significant elements. As predicted by the gestalt laws of simplicity and continuity, we assume that the flowlines pass unbroken underneath the machines they connect [12]. We tend, therefore, to see five more-or-less vertical and tapering flow lines, four of which have bends towards their bottom ends.

Now for the purposes at hand it will be convenient to deal with classes of similar significant elements rather than individuals, as frequently diagrams comprise multiple presentations of matching graphic devices. Here we have another problem, which we might call the taxonomist's dilemma.
Too fine a discrimination will result in every individual element being assigned its own class, whereas too coarse a distinction will result in too much being subsumed under a single class. The problem is, what can be taken as similar? For example, in Figure 3-9 we might make a class of all the significant elements we take to be flowlines. This would of course include not only the more or less vertical flowlines already mentioned, but also the two horizontal flowlines of the pre-1948 period. Conversely, if we are very strict in what we take to be similar, we might distinguish between the straight and bent flowlines, or even between those which bend to the right as opposed to the one which bends to the left. This does not seem terribly useful so we need a more practical device for establishing a class of significant elements. Here again we must take account of the intention of the picture. We must ask whether some similarity of graphic configuration implies a similarity of meaning and, conversely, whether any discernible difference amongst a group of elements which might otherwise be judged to be the same implies that a difference of interpretation is called for. I think we may safely say that the difference in direction, form and colouration of flowlines provides us with two classes of flowline, one set for the files and spark wheels period prior to 1948 and one for the post-1948 machine tool period. Further sub-division seems inappropriate as the discernible differences do not appear to be matched with any differences of meaning.

If we now consider the line drawings of the machine tools we notice that each one is different, a distinct individual representing a separate model. However, their style of drawing and general appearance have similarities which tend to make us consider them collectively. Some, we observe, are coloured grey and others are yellow. This seems unlikely to be an accidental feature, especially as star-shaped and circular symbols are placed respectively against the two colours. This coding obviously has a separating function and gives us two classes of significant elements.
By this process we can arrive at an inventory of the classes of significant elements contained in the diagram, and of course it is possible that some classes may contain only one element. This method has been used to make a detailed analysis of the diagram given in Figure 3-9, and of an additional specimen. These analyses are given in Chapter 9. Having taken diagrams apart in this fashion, next we must put them back together again, so to speak, in order to assess and classify the diagrammatic function of their significant elements. Echoing the basal contention of gestalt psychology, it is the interaction between the elements of a diagram which give it meaning and not the parts taken separately. The theoretical basis for the process of classifying the significant elements of diagrams is introduced in the last section of this chapter. This is Section 3.5, entitled 'Syntactics, semantics, and pragmatics'. But in the next two sections some parallels are pointed out between the grammatical structure of sentences and the graphical structure of diagrams. Some additional terminology is also introduced.
3.3 Parsing diagrams

It has been shown that diagrams may be analysed into what I have called significant elements. In some cases these elements are merely intended to say 'here is something', but in fact much more could be inferred. A thing referred to in a diagram may actually have no particular location, size, colour, or shape, but the significant element which represents it must have all these qualities. When using diagrams to represent some state of affairs, one cannot rid oneself of these accidental attributes which, amongst other characteristics, distinguish communication through static two-dimensional space from speech in all its forms. In speech we can use abstractions like 'man' or 'anything', but there is no way to translate such concepts into pictures. No matter how high the degree of schematization used, any graphic mark will have particular attributes. Nevertheless it is usually through schematization that generality is suggested. It is in this connection that Arnheim (1970 p280) notes that,

'Roundness is chosen spontaneously and universally to represent something that has no shape, no definite shape, or all shapes.'

This same restriction, which sometimes makes us state too much in diagrams, also limits their range of application, unless recourse is made to symbolic coding. This is especially so where a denial of some situation is involved. The problem is neatly stated by Gombrich (1974 p243) thus:

'The assertion that statements cannot be translated into images often meets with incredulity, but the simplest demonstration of its truth is to challenge the doubters to illustrate the proposition they doubt. You cannot make a picture of the concept of a statement any more than you can illustrate the impossibility of translation.'

Now, returning to the possibility of a significant graphic
element carrying the minimal assertion, 'here is something', it should be noted that certain of its constituent features may also be capable of having additional meaning ascribed to them. For example, the particular configuration of an element may be recognised as having the appearance of a such and such found in the real world. On the other hand an element may be judged not to refer to any actual object, but will nevertheless have physical attributes shared by many things. A patch of colour may change width along its length, a characteristic found in many objects, natural and man-made. In this case reference may be said to be to the reality of the page itself as, in a sense, no actual object beyond the diagram is signified. Rather the reference may be to some generalizable quality exemplified in the particular patch of colour.

Meaning may also be ascribed to particular graphic configurations by convention, thus making the significant element a symbol. That is, amongst some community of users, such and such a device is taken to have such and such a significance by prior agreement.

But for a diagram to be a diagram it must describe a relationship by its spatial configuration. It cannot just say, 'there is something' or 'here is a particular sort of thing' nor can it simply exemplify a particular physical characteristic. By definition a relationship must comprise at least three parts. There must be a minimum of two participants, the third part being the relation between them [13]. In the case of a diagram it is the interaction of its elements which carries the diagrammatic or relational meaning. Stated most generally then, a diagram or part of a diagram will say, 'this stands in such and such a relation to this'. Consider Figure 3-10 which may be thought of as saying, 'A is connected to B'. We might then say that 'A' is the equivalent of a grammatical subject and its connection with 'B' is the predicate; thus the line serves a verb-like function for the nouns A and B. Of course 'B' could just as easily be the subject in the

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[13] Bertin (1981 p63-64) tells us that, 'Every "graphic structure" [graphique] is transcribed from a table of data. A datum is the relation between two elements...Every grouping of data can therefore be structured in the form of a table which designates x as the component called "objects" and y as the component called "characteristics"...All graphs, diagrams, or maps are therefore truly the transcription of a double-entry table.'
same way that, in speech, sentences may be reorganized to swap object with subject without altering their general meaning. Thus 'B' is connected with 'A' is equally valid, although this would not necessarily be the case if, say, a directional arrow were included.

Let us look again at Figure 3-9. Here also, the significant elements forming the flowlines seem to function like verbs. Amongst other things they display the antecedent of any particular product, which one might paraphrase as, 'this machine is prior to this machine'. Thus the depictions of the machines take on a subject/object relation. If we study the individual images of the machines we notice that while they are consistent with the rules of perspective within themselves, their spatial relations with each other are not. However the arrangement of images is not arbitrary but is governed by their appropriate place on one of the flowlines. Unlike the depictions of the machines, the flowlines appear to occupy the non-perspective space of the page itself.

It is, then, apparently possible to portray different discontinuous spaces and times in a single diagram, as suggested earlier. Each machine occupies its own space which is disconnected from the space of other machines and we are to imagine each placed at a different period in time. The flowlines share the same period in time with the machines, where they are adjacent. However, the flowlines occupy a two-dimensional space different from the three-dimensional space of the machines.

A similar concept has been identified elsewhere in a study of the significance of the allegorical tableaux of the seventeenth century (Ong 1959). Indeed the parallel with present concerns is indicated in the title of the piece in question: 'From allegory to diagram in the renaissance mind...'. Ong tells us (op cit p425) that in the typical allegorical tableau,

'...the governing principles may be considered to be more or less naturalistic pictorial representation
on the one hand and on the other some kind of organisation in space which is not naturalistic but artificial, schematic, or diagrammatic.'

Indeed Ong has asserted that it is the presence of a non-naturalistic element which characterizes the allegorical tableau. He gives the example of the title page of Hobbes' *Leviathan* (1651). This shows,

'...the body of a huge man (the commonwealth)... pictured as an aggregate of little men (individuals). These little men are drawn each in an individually naturalistic fashion but are not presented as acting naturalistically on one another. Each is simply inserted next to the others so that together they form a spatial aggregate filling up the outline of the commonwealth's body, which is itself an extraneous framework uniting them.'

The frontispiece shown in Figure 3-11 was published late in the last century and shows a more recent example of what might well be called an allegorical tableau. General Booth (1890) tells us that,

'The Chart is intended to give a bird's-eye view of the Scheme described in this book, and the results expected from its realization.'

This chart is then intended to be a kind of diagram of Booth's text.

Returning to Ong's (op cit) study of seventeenth century tableaux, he observes that sometimes an otherwise 'naturalistic' picture can have its 'realistic space... proportionally denaturalized' by the surrounding typographical 'non-realistic' space. He also speaks of the 'peculiarly neuter space' of the allegorical tableau. I do not propose to adopt Ong's terminology here, although the concept of different sorts of space will be useful.

The different kinds of spatiality found in diagrams and their relation to the function of significant elements will be considered in more detail in the following section.
Now we must keep clear the distinction between the situation apparently depicted by a diagram and what it is that situation is supposed to stand for. The situation depicted I will term the **content model** to distinguish it from the content proper, or that which the diagram represents or means [14]. For example, in Figure 3-12 the diagram depicts a content model we take to be a tree. Disks are attached to the branches and it is topped with a crown. However, the content itself is concerned with some form of taxonomy. As pointed out earlier, what is taken as a significant element is dependent on the intention of the picture. This being the case, significant elements more properly belong to the content model depicted by the diagram, than to the diagram seen as a collection of marks on a piece of paper. Where I wish to refer to a set of marks on a piece of paper (or other plane surface) which has a communicative function, but may or may not be a diagram, I shall use the generic term **graphic display**.

It was also pointed out earlier that some significant elements can be thought of as being equivalent to noun phrases. These perform like grammatical subjects and objects and in certain cases the classifications seem interchangeable. Other elements may be thought of as operating like verbs. In some cases the apparently empty space between elements may also function in a verb-like manner, as will be described later. In all these cases it does not seem to be necessary for the participating elements to appear to share the same time or space [15]. A content model may not, then, necessarily show a single homogeneous space, but may comprise what we take to be various discontinuous spaces.

It will be clear from this that the content model is always...
a mental construction. It is the spatial interpretation we place upon the marks before us in a graphic display.

Taking a lead from Euler, the different spaces of our content model may be referred to by their grammatical functions. When describing his system of representing syllogisms by circles [16], Euler (Brewster and Griscom 1839 p.340) tells us,

'Hence it follows that the representation of an affirmative universal proposition is that in which the space A, Fig. 43 [shown here as Figure 3-13], which represents the subject of the proposition, is wholly contained in the space B, which is the attribute [or predicate].'

I propose to use grammatical categories to describe diagrammatic space, which in effect is the reverse of Euler's idea of using space to stand for grammatical categories. This provides the terms:

- **subject space**, and
- **predicate space**.

Predicate space may be further analysed into

- **verb space**, and
- **object space**

where the verb space establishes the relationship between subject and object spaces. A space may be referred to as a

- **noun space**

where there is no need to ascribe it the function of either subject or object.

So, some graphic displays are diagrams, and the situation they depict may be referred to as the content model. The content model is made up of both noun and verb spaces. Significant elements occupying noun space function like nouns and may serve as subjects or objects. Significant elements occupying verb space function like verbs. Figure 3-14 summarizes this hierarchy.

It should be noted that whilst there must always be significant elements occupying the noun space, there do not necessarily have to be significant elements occupying verb space, hence the dashed line in Figure 3-14. This point is
elaborated in the opening section of Chapter 9, which deals with the analysis of specimen diagrams. Another level of analysis which extends this particular model is also introduced in Chapter 9 [17].

This idea of grammatical spaces may be compared with an earlier proposal made by Knowlton (1966 p174).

'A visual-iconic representation can be thought of as having three "parts": the elements, their pattern of arrangement, and their order of connection. Thus, in a circuit schematic of a radio receiver, the elements would be the capacitors, resistors, etc. Pattern would refer to the spatial arrangement of these elements. The order of connection would refer to the sequence in which these elements were connected by copper wires or other conductors. (The conductors are not here regarded as elements, though for some purposes it may be useful so to regard them.)'

Knowlton observes that while the spatial arrangement of the elements of a circuit schematic are ordinarily 'arbitrarily portrayed' the 'order of connection of the elements...is identical with...the actual physical circuit'. As a consequence of this the schematic is an 'iconic representation'.

'A visual representation will here be regarded as iconic if at least one of its three categories of "parts" - elements, spatial arrangement of elements, or order of connection of elements - is non-arbitrary.' (op cit p175)

The fact that diagrams are made up of various interacting elements which do not necessarily signify in a homogeneous manner seems to be agreed. However, the division of these elements into the three parts suggested by Knowlton is not applicable here. This scheme may fit a circuit schematic, but I would suggest that it is insufficiently general to fit the range of specimens considered in this investigation. For example, the elements of a bar chart may not have an order of connection, but they do have other
important interrelations. What is needed is something more
general. That is why I have introduced the concept of noun
and verb spaces. Within any single diagram any one of
these categories may itself comprise many separate spaces,
and any space of any category may be contiguous with any
space from any other category. I would argue that this
more flexible concept can account for the diverse nature of
diagrams. This of course is not a complete explanation of
how we unravel complex diagrams, but it may offer some
clues.

The extent to which this grammatical analysis is applicable
to what might be called a 'realistic picture' will be
considered in Chapter 5 on the 'Modes of diagrammatic
correspondence'.

In the final section of this chapter we consider the
classification of significant elements. Having analysed a
diagram into its various constituent parts, some further
scheme is needed for assessing how meaning may be ascribed
to it.
Morris (1938 p35) proposed that signs might be studied in terms of their syntactic, semantic and pragmatic rules. Briefly stated,

'Syntactical rules determine the sign relations between sign vehicles; semantic rules correlate sign vehicles with other objects; pragmatic rules state the conditions in the interpreters under which the sign vehicle is a sign.'

Cherry (1978 pp223-224) has stressed that these categories are not mutually exclusive. Each depends to some extent on the other, as is indicated in Figure 3-15 which shows them as successive levels of abstraction.

The character of these distinctions is translated into pictorial terms by Goldsmith (1978 p113) who uses a Charles Addams cartoon as an example. The cartoon shows a pair of unicorns stranded on an island, watching the ark sailing away (see Figure 3-16). Goldsmith thinks that little difficulty should be encountered in interpreting the drawing at the syntactic level:

'Reasonable attention has been paid to the perspective principles of overlap, textural recession and so on, and the bounds of each separate image can be discerned without too much trouble.'

However, at a semantic level the images require identification and,

'A young child might mistake the images in the foreground for horses and be satisfied with "boat" for the second significant element.'

At the pragmatic level the point of the drawing is lost if the viewer is not familiar with the story of Noah and is unaware of the rarity of unicorns.

Such concepts as syntactic and semantic rules are normally associated with spoken and written language, but
as illustrated above the terms may be extended to pictorial communication. Goldsmith (op cit) has shown in her dissertation that the distinctions offered by this extended application are at least theoretically useful and may have practical value as well.

This present investigation is concerned in varying degrees with all three levels of analysis outlined above. It is concerned with how diagrams relate to what it is they depict (semantic level), and with their principles of graphic organization (syntactic level) which direct their interpretation (pragmatic level). These semiotic levels of analysis give the main categories under which diagrams are interpreted by their readers. The syntactic, semantic, and pragmatic levels therefore offer a useful basis for part of the scheme of classification proposed here.

At the pragmatic level we shall consider how the diagrammatic elements relate to what it is we take the diagram to represent. In this dissertation this relation is called

\textit{mode of correspondence}.

At the semantic level we shall consider the way in which the graphic image relates to the various elements perceived in the content model, and here this is called the

\textit{mode of depiction}.

At the syntactic level we shall consider the way in which a significant element relates to others and thus contributes to the relational meaning of the diagram. This is called the

\textit{mode of organization}.

The modes of correspondence, depiction, and organization are nominated as representing the principal variables available for the design of diagrams.

In Chapter 5 it is proposed that the mode of correspondence
may range from the 
   literal, to the 
   non-literal
There is a literal mode of correspondence when there is a high degree of similarity between a part of the content model and what it is we take it to represent. The concept of there being any kind of resemblance between a picture and what is pictured has been challenged by some commentators. Chapter 5 is therefore preceded by a chapter entitled 'Problems concerning theories of picturing' which deals with some of these arguments.

As it is also proposed that the non-literal mode of correspondence functions in a metaphorical way, Chapter 5 is followed by a chapter dealing with 'Metaphor in diagrams'.

Chapter 7 describes the 'Mode of depiction' which can range from the 
   figurative, to the 
   non-figurative.
This concept has similarities to the 'scales of iconicity' of Moles (1968).

Chapter 8 describes an important aspect of the thesis presented here and is concerned with the fundamental modes of graphical organization available for making diagrams.

The terms literal and non-literal, associated with the mode of correspondence, and the terms figurative and non-figurative, associated with the mode of depiction, will be re-introduced in the appropriate chapters and explained more fully.

Chapter 4, which follows, prepares the way for describing the 'Mode of correspondence' in Chapter 5.
Summary

Whilst acknowledging that it may not be very useful to look for the equivalent of phonemes or morphemes in pictures, certain parallels between graphic communication and language have been pointed out. I have argued that certain borrowings from linguistic terminology are therefore legitimate and may be helpful in analysing diagrams.

Wittgenstein's (1961) 'picture theory of meaning' is mentioned and the 'existential graphs' of Peirce (4.347 ff) are introduced. Shephard's (1975) work on the internal representation of three-dimensional objects is also mentioned.

The heterogeneous nature of the signifying codes found in diagrams has been pointed out.

The term significant element has been introduced to describe the primary unit of analysis in the scheme to be proposed here. In this connection reference was made to the gestalttheorie principles of segregated wholes. It was suggested that for the purposes of analysis it may be convenient to deal with classes of significant elements whose meanings are judged to be generally equivalent.

I made the observation that parts of some diagrams would seem to behave either like nouns or verbs.

A comparison has been made between the apparent spatial organization of allegorical tableaux of the seventeenth century, and that found in some diagrams which appear to show more than one kind of space in a single depiction.

I have proposed the term content model to distinguish between the situation depicted by a diagram and its actual content, or what it is the diagram represents. The generic term graphic display has also been introduced.
I have proposed that the different spaces contained in the content model may be referred to by their grammatical functions. This gives us the terms subject space and predicate space. Predicate space may be analysed into object space and verb space. Where it is unnecessary to indicate whether a space serves the function of a subject or an object, the term noun space may be used.

Morris's (1938) categories for the study of signs in terms of their pragmatic, semantic, and syntactic rules have been introduced and adopted. Each of these is to be dealt with in the chapters on the Mode of correspondence, Mode of depiction and Mode of organization respectively. Certain other terms were mentioned and these will be re-introduced later.
Chapter 4

PROBLEMS CONCERNING THEORIES OF PICTURING

4.1 Problems of iconism

4.2 An iconoclastic view

4.3 Critique of iconism

4.4 Generative theory

4.5 Similitude in diagrams

Summary

"I won't be sorry when somebody gets this perspective problem sorted out."
4.1 Problems of iconism

In this dissertation I draw a distinction between literal and non-literal modes of correspondence. This distinction relies on the concept that there is a sense in which some two-dimensional representations may be regarded as similar in some respects to the objects they depict [1]. In the terminology of semiotics, signs of this kind are called icons. Such signs are often said to be 'motivated' by their 'referents' [2]. However, there is much acrimonious debate about the very notion of iconicity and Sebeok (1979 p111) has identified two opposing groups whom he characterizes as iconophiles and iconoclasts. The first group is represented by those who simply take icons for granted, and the other by those who support the view that there are no iconic signs at all. In order to justify the position adopted for the thesis presented here, it will be necessary to consider some of the positions taken on iconism.

Firstly, the views of an 'iconoclast' are put forward. These views are presented with some counter arguments of my own and those of others.

Then a more moderate 'Critique of iconism' is presented; aspects of this position are adopted here.

Next a 'Generative theory' of picture perception is introduced in which perspective plays an important role.

Finally the position adopted for this study, that there can be such a thing as 'Similitude in diagrams', is outlined.
4.2 An iconoclastic view

Goodman (1976) is a well known and often cited adversary of the idea of any absolute or constant relation between a picture and its object. Some of his arguments, put forward in *Languages of art*, will be examined. Some preliminary comments on Goodman's terminology should be made first. Other writers often use the term 'representation' in a general sense for all varieties of reference by both pictorial and nonpictorial signs. Goodman (op cit p4), however, makes it clear that he describes pictorial depiction as 'representation', while verbal and other nonpictorial signs are referred to as 'nonrepresentational'. This should help to make clearer the sense of some of the quotations which follow.

Goodman (op cit p3) commences by rejecting what he suggests are commonly held views about resemblance and representation as expressed in such formulae as:

'A represents B if and only if A appreciably resembles B'

or:

'A represents B to the extent that A resembles B' [3].

He (ibid) suggests that some of the faults are obvious enough, pointing out that,

'An object resembles itself to a maximum degree but rarely represents itself.'

Neither does,

'One pair of very like objects represent the other,'

Automobiles off a production line, for example, do not represent one another. He (op cit p4) points out that,

'...resemblance, unlike representation is reflexive. Again unlike representation, resemblance is symmetric: B is as much like A as A is like B, but while a painting may represent the Duke of Wellington, the Duke doesn't represent the painting.'

This is true, but in my judgement the fact that resemblance is reflexive and representation is not does not exclude resemblance from participating in representation. It
merely means the terms are not synonyms. Cameron (1979 p750) observes that,
'the distinction Goodman fails to comprehend is that
the picture not only resembles the Duke but also
connotes a system of pictorial reference.'[4]

Goodman (op cit p4) thinks it is not obvious what
correction to make to the formula, but, perhaps in
anticipation of the sort of objection Cameron has raised,
suggests that we may add the prefix:
'If A is a picture...'
This is apparently inadequate because on the one hand,
'if we construe "picture" as "representation", we
resign a large part of the question: namely, what
constitutes a representation.'
On the other hand
'even if we construe "picture" broadly enough to
cover all paintings the formula is wide of the mark
in other ways.'
Goodman gives the example of a Constable painting of
Marlborough Castle, pointing out that it is more like
another picture than the castle, while representing the
castle and not another picture.

This of course is true, but only in certain respects. For
instance the picture, like others, is made of paint on
canvas and the castle is made of stone. However, any
similarities amongst pictures in terms of the materials out
of which they are manufactured, and any lack of such
similarity between pictures and what they picture, is
incidental. I would assert that, in the example given by
Goodman, there are other similarities between the object
and picture which make it represent Marlborough Castle and
not, say, the Duke of Wellington.

However Goodman (op cit p5) believes:
'The plain fact is that a picture, to represent an
object, must be a symbol for it, stand for it, refer
to it; and that no degree of resemblance is
sufficient to establish the requisite relationship
of reference.'
It may be that resemblance alone is insufficient for representation but I hold the view that within a picturing context, resemblance participates in referring to an object. Ayer (1968 p131) suggests that,

'What makes [an image] a sign, if it is one, is that it comes under a convention in terms of which resemblance is treated as a method of representation.'

However, for Goodman (ibid),

'denotation is the core of representation and is independent of resemblance.'

He anticipates our next question: In that case

'What does pictorial denotation have in common with, and how does it differ from verbal or diagrammatic denotation?'

Goodman admits that a plausible answer might be,

'that resemblance, while no sufficient condition for representation, is just the feature that distinguishes representation from denotation of other kinds.'

He (op cit p6) considers a further reformulation along these lines, which he also rejects:

'If A denotes B, then A represents B just to the extent that A resembles B.'

I also reject this formulation. As Ayer (op cit pl31) has noted,

'the resemblance between an image and what it is taken to signify need not be very close.'

and Arnheim (1974 p159) has pointed out that,

'since representing an object means showing some of its particular properties, one can often achieve the purpose by deviating markedly from "photographic" appearance. This is most evident in diagrams.'

I agree that it cannot be said that the less the degree of fidelity in an image the less it pictures its object. In the case of some caricatures the opposite effect may be observed (see Perkins and Hayes 1980). However, it does not follow that there is no correspondence at all between a picture and its object which enables the one to represent the other.
Next the 'copy-theory' of representation is dismissed. Goodman (op cit p6) offers the following cock-shy:

'To make a faithful picture, come as close as possible to copying the object just as it is.'

Of course a picture can never be a copy of something 'just as it is'. This is agreed. However, Goodman goes on to reject the notion of copying any aspect of the way an object looks, which is where he and I part company again.

He (op cit p7) rejects the following parameters for copying in a picture.

'the way the object looks to the normal eye, at proper range, from a favourable angle, in good light, without instrumentation, unprejudiced by affections or animosities or interests, and unembellished by thought and interpretation.'

It is of course the latter injunction concerning the condition of the viewer's mind which causes the difficulties. Here Goodman enlists the aid of Gombrich (1977) who insists that there is no 'innocent eye'. For Gombrich vision is 'theory laden', that is, visual perception is always determined by past experience. For Goodman any idea of copying in a picture any aspect of a scene is prevented by the inability to specify what it is that is to be copied. This is because what is seen is dependent on individual past experience. However, what Goodman rejects, other authorities seem to hold as important to their theories. For example, Arnheim (1969) argues that objects must be represented in their most characteristic aspects for their successful depiction at the 'everyday level of perceptual abstraction' [5]. He asserts that certain projective aspects contain references which point beyond themselves to subsequent views while others do not. His example of an uncharacteristic aspect is the bird's eye view of a thin man in a large sombrero. See Figure 4-1.

In my view the notion of characteristic aspects or views is a valid one. In this connection it is interesting to

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observe that the representational convention adopted by engineers, namely orthographic projection (British Standards Institution 1972), often produces uncharacteristic aspects and requires several separate views in order to specify an object. The well known illustration in Figure 4-2 shows the kind of difficulties which can arise. The computer generated rotations in Figure 4-3 show the origins of the ambiguities. One could easily select from the series a single view which would serve as a basis for a far less equivocal depiction than all three views of Figure 4-2 taken together. Using the standard conventions for lines, such a single view might look like Figure 4-4. The inability to specify precisely what constitutes a characteristic view does not mean that they do not exist.

Goodman feels that he is not required to argue at any length the case for imitation having little to do with representation. He believes that Gombrich in particular has amassed overwhelming evidence to show that the way we see and depict varies with our experience, attitudes, etc. However, Goodman (op cit p10) thinks that Gombrich's (op cit) attitude towards perspective is at odds with the case for the relativity of vision and pictorial representation.

'Gombrich derides "the idea that perspective is merely convention and does not represent the world as it looks".'

Goodman takes an opposite view. Whilst allowing that the laws of the behaviour of light are no more conventional than any other scientific laws, he argues that perspective laws based on the standard projective model, such as shown in Figure 4-5, are no criteria for the fidelity of pictorial representation. The usual formulation of the theory is that the pattern of light proceeding from a picture to the eye should match the pattern of light rays which would meet the eye if the observer were viewing the depicted scene directly.

Firstly Goodman (op cit p11) points out that any number of
Figure 4-3
Computer rotations produced in 1980 by Tim Goss.
objects at any number of distances and angles will deliver
the same bundle of light rays to the eye (see Figure 4-6).

'Indentity in the pattern of light, like resemblance
of other kinds, is clearly no sufficient condition
for representation.'

Whether this is sufficient condition or not, it certainly
does not follow from this that any pattern of rays can
picture any object, even if as Goodman (op cit p5) points
out,

'almost anything can stand for anything else...'

Goodman then proceeds by considering and dismissing
perspective as a criterion of correct pictorial
representation where denotation is otherwise established.
He (op cit p12) gives the conditions of viewing as follows:

'The picture must be viewed through a peephole, face
on, from a certain distance with one eye closed and
the other motionless. The object also must be
observed through a peephole from a given (but not
normally the same) angle and distance, and with an
unmoving eye.

This is at variance with the usual requirements on a number
of points. Firstly it is only necessary for the eye to
have a fixed point of view, and a peephole is one way to
achieve this. Secondly, the requirement for a motionless
eye is unnecessary. For all practical purposes, the eye,
when scanning, may be thought of as swivelling about a
fixed point within its socket, this point corresponding
with its optical centre. A motionless head would therefore
be a more reasonable specification. Thirdly, although it
is usual for the viewing distance of picture and object to
be different, the relative angles between the rays of light
subtended at the eye should be the same for points on the
object and corresponding points in the picture. Quite what
is meant by saying that the given angle of viewing is not
normally the same is unclear to me. Fourthly, although the
viewing distances for picture and object may be different,
they are strictly related. It is these misconceptions
about the rules of perspective which lead Goodman to draw
Figure 4-5
The theory of perspective
From: Malton (1776, plate IV, Fig 14)

Figure 4-6
Wire-screen gates from:
Gombrich (1977 p212)
various erroneous conclusions which will be dealt with a little later.

However, such a viewing situation is anyway dismissed by Goodman as establishing the fidelity of an image. He claims that under the specified conditions the retinal image promptly disappears, citing as his authority the paper of Riggs et al (1953) on 'The disappearance of steadily fixated visual objects'.

Unfortunately the experimental conditions described by Riggs et al are not those for correctly viewing perspective scenes, neither are they the conditions Goodman supposes are correct, unless the motionless eye injunction is strictly enforced. In the experiment in question, this is done by means of a complex apparatus involving the projection of an image onto a viewing screen via a mirror fixed to a contact lens on the subject's eye. The apparatus ensures that any movement of the eye is compensated for by a movement of the viewed image. Thus the image occupies a constant location on the retina. It seems that under these conditions subjects do indeed report that the image disappears after a short while. However, this is not what happens when the eye views a perspective scene from a fixed vantage point, as might be achieved by the use of a peep-hole. If this were the case, Victorian peep-shows would never have worked! As the eye scans a fixed perspective the visual image travels across the retina, and even when one stares constantly at a given point there are very small high speed movements or terrors of the eye of which the observer is unaware [6]. These movements prevent the kind of image saturation which results in scenes disappearing. The scanning movement of the eye relative to a fixed perspective can be thought of as being similar to moving either a flat screen from side to side, or a curved screen about its centre of curvature in front of a projector. The moving screen introduces no distortions to the projected image through its movement.

In answer to Goodman's (op cit p13) question:

(6) These movements of the eye are well known and are reported in many standard texts dealing with the physiology of our perceptual mechanisms.
'What can the matching of light rays delivered under conditions that make normal vision impossible have to do with fidelity of representation?'

I would say: quite a lot, particularly as it does not make vision impossible as Goodman suggests. As to normal vision, I would counter that picturing does not attempt to replicate normal vision.

Goodman (ibid) then retreats slightly by saying:

'perhaps enough eye motion could be allowed for scanning but not for seeing around the object.'

This is in fact one of the corrected conditions I have specified above.

Even allowing for a moving eye, Goodman asserts that the specified conditions of observation are grossly abnormal and that 'the matching of light rays under such extraordinary conditions' is no grounds for a measure of fidelity. Certainly the correct conditions for viewing perspective scenes are abnormal when compared with everyday vision but, as pointed out already, perspective should not be thought of as copying normal vision. Perspective picturing is, rather, concerned with depiction on a flat plane of how things look from a single vantage point at a single moment, and with nothing else. It should not be regarded as an attempt to copy reality. The requirement, then, to view a perspective from a point which corresponds to the point from where the depicted scene was viewed seems to me perfectly reasonable. But Goodman (op cit p13) thinks it an 'odd and futile' argument for the fidelity of perspective that the light rays from a picture can be made to match those from the object under the specified conditions. The reason for this is apparently that a picture far out of perspective could also be made to yield the same matching pattern of light with suitably contrived lenses. The suggestion is that such viewing conditions are no more abnormal than the correct viewing requirements for perspective. This of course is plainly not the case, as in perspective there is no requirement to interpose lenses, mirrors or any other devices to modify the light proceeding.
to the eye, so any suggestion of equality of conditions is nonsense. The possibility of correcting pictures far out of perspective therefore proves nothing.

Goodman (op cit p14) rightly points out that under normal gallery conditions pictures are not viewed from a single perspective point. This is so, and the fact that perspective views still work when not viewed 'correctly' is evidence of the power of this remarkable and strikingly convincing method of depiction. It has in fact been argued that the perception of depth relations in perspective pictures is most accurate when they are viewed from the wrong station point [7]. It is suggested that in such cases the flatness of the picture is more apparent, and viewers are consequently tripped into a pictorial mode of perception which compensates for the information concerning the surface of the picture and perspective distortion. The conditions for viewing perspectives, and interpreting them correctly, do not necessarily have to match those for correctly making a perspective. When we view a perspective from the 'wrong' point, I suggest we see a perspective of a perspective, which, when the displacement is not too great, seems to present no problem of interpretation for us. But Goodman believes that trying to make a picture deliver a bundle of rays matching its object is pointless, if it were possible, and concludes that picturing,

'is not a matter of copying but of conveying...of "catching a likeness" [rather] than of duplicating - in the sense that a likeness lost in a photograph may be caught in a caricature'

For certain kinds of picture this may be to some extent true.

'How this is best carried out depends upon countless and variable factors, not least among them the particular habits of seeing and representing that are ingrained in the viewer.'

This also seems reasonable, but Goodman (op cit p14) continues:

'Pictures in perspective, like any others have to be read; and the ability to read has to be acquired.'
The eye accustomed solely to Oriental painting does not immediately understand a picture in perspective. In my view, Goodman's arguments, as exemplified in this last statement, deny perspective its special position as a means of representation by their excessive emphasis on the learning requirement. These and similar arguments by others are probably informed by the evidence that people from non-western cultures experience difficulty in interpreting perspective pictures. However, some of this evidence is anecdotal and the results from such cross-cultural studies as have been carried out need careful evaluation. Following a review of the literature, Hagen and Jones (1978 p206) make the following observations:

'We may conclude fairly confidently that the perception of fully coloured and textured pictures is relatively independent of culture and the black-and-white convention primarily poses problems of attentional deployment. In general, edge information alone in pictures seems to provide an adequate basis for the perception of object and even on Embedded Figure Tests detection errors are rarely reported.'

Kennedy (1974) goes as far as suggesting that depiction by line is universally understood as a result of an inborn capacity and will therefore occur everywhere.

The view I support is that the culture-specific nature of pictures has been overstressed by certain commentators. As Hagen (1980 b) has pointed out, what is striking about pictures from various ages and cultures is not how different they are, but how similar. This observation will be taken up again later in this chapter.

However, returning to Goodman's (op cit p15) views concerning perspective he states:

'So far I have been playing along with the idea that pictorial perspective obeys laws of geometrical optics, and that a picture drawn to the standard pictorial rules will, under the very abnormal conditions outlined above, deliver a bundle of light
rays matching that delivered by the scene portrayed. Only this assumption gives any plausibility at all to the argument from perspective; but the assumption is plainly false.'

The evidence Goodman proceeds to offer in support of this claim is based on reasoning involving an argument which has perplexed many generations of artists who have concerned themselves with perspective. Goodman takes the line that, following the pictorial rules, railroad tracks running away from the observer are drawn converging while telephone poles and other verticals are drawn parallel. He (op cit p16) asserts that,

'By the "laws of geometry" the poles should also be drawn converging. But so drawn, they look as wrong as railroad tracks drawn parallel?

So they do, but then its quite wrong to say the "laws of geometry" require verticals to converge. All this proves is that Goodman does not understand the rules he is trying to discredit, which, properly stated, assert that lines parallel to the plane of the picture project into lines which have the same angles. So in any scene with a vertical picture plane, all verticals will be represented by lines which are also vertical. All these sorts of apparent problems were cleared up once and for all in the famous treatise on the mathematical foundations of perspective by Brook Taylor (1749). One attempt at making this work more accessible to the non-mathematical artist is the magnificent folio volume by Malton (1776). This contains many superb engravings, including various folding figures which illustrate some of the theorems. In view of the existence of these works and the numerous books which followed, it is surprising that objections of the sort which Goodman describes are still raised.

However, he (op cit p17) proceeds to give a demonstration, which with the aid of the diagram shown in Figure 4-7 aims to show how,

'the bundle of light rays delivered to the eye by a certain picture drawn in standard perspective is
Figure 4-7
From: Goodman (1976 p18)

Figure 4-8
From: Goodman (1976 p18) with additions (lines h, k, and l)
very different from the bundle delivered by the facade [the picture depicts].'
The argument runs as follows:

'...an observer is on ground level with eye at a; at b,c is the facade of a tower atop a building; at d,e is a picture of the tower facade, drawn in standard perspective and to a scale such that at the indicated distances picture and facade subtend equal angles from a. The normal line of vision to the tower is the line a,f...the normal line of vision to the picture is a,g. Now although picture and facade are parallel, the line a,g is perpendicular to the picture, so that the vertical parallels in the picture will be projected to the eye as parallel while the line a,f is at an angle to the facade so that vertical parallels there will be projected to the eye as converging upwards.'

If we are to infer from this description, as I th n: we are, that the vertical parallels in the picture are supposed to be the perspectives of the vertical parallels of the facade, then we do not have a 'standard perspective' as a given. What Goodman omitted from the diagram is the position of the plane of projection which produced the perspective d,e when looking at the facade. In Figure 4-I have added h,i,p, which is the only place where this plane could be when viewing from a if a standard perspective is required. This dispenses with Goodman's apparent objection concerning verticals in the picture. In this case the verticals on the facade would indeed project into lines converging upwards in the picture. His suggestions about repositioning the picture at h,i and j,k to try to make the light rays match are therefore irrelevant. He in any case dismisses these on other grounds. The one valid suggestion he makes to correct matters is to view the tower from m. He dismisses this on the grounds that 'we do not...elevate ourselves to look squarely at towers'. This seems a poor argument as we might well be standing on a hill, looking out of the second storey window of the building opposite, or in any number of normal situations.
Anyway, if our plane of projection was sighted at $g,r$ which I have added to Figure 4-8, the perspective at $d,e$ would show the verticals of the tower as vertical in the picture. Quite apart from the normality of the viewpoint, that is how the resulting perspective would appear taken from $m$. Goodman (op cit p19) concludes his dismissal of perspective as follows:

'This argument by itself is conclusive, but my case does not rest upon it. The more fundamental arguments advanced earlier would apply with full force even had the choice of official rules of perspective been less whimsical and called for drawing as convergent all parallels receding in any direction.'

I have shown that the argument referred to is by no means conclusive. The rules of perspective are, within themselves, quite consistent. Given a fixed vantage point and a fixed plane of projection, everything else follows, and is not a matter of 'choice', 'whimsical' or otherwise. All that Goodman has shown by the argument in question is that if one ignores the rules of perspective, the resulting picture will not match the scene depicted. Of course this says nothing at all about the validity of the perspective method of depiction.

As pointed out earlier, I remain unconvinced by his more fundamental arguments.

From the aforegoing it will be seen that Goodman rejects notions of there being any useful sense in which a picture can be said to be similar to what it depicts.

For him (op cit p33 ff)

'realism is relative, determined by the system of representation for a given culture or person at a given time...a matter of habit...That one picture looks like nature often only means that it looks like the way nature is usually painted.'
He (op cit pp40-41) stresses the analogy between pictorial depiction and verbal description but stops short of calling a system of depiction a language.

'The question of what distinguishes representational from linguistic systems needs close examination.'

I agree with Goodman that it is not simply the case that 'symbols grade from the most realistic ones to descriptions'. However, our reasons for this agreement do not exactly coincide. As already stated, for Goodman realism is a matter of habit, but he accedes that 'the most commonplace nouns of English have not become pictures' (op cit p40). What then is his theoretical difference between 'pictures and paragraphs'?

Goodman (op cit p127 ff) proposes the concept of 'notationality'. He stipulates certain rigorous conditions with which a symbol system must comply to be classed as strictly notational. Different systems may be distinguished by the various ways in which they violate these conditions. Quite simply, systems of pictorial representation are non-notational.

It seems to me that according to Goodman, a picture is a picture when it does not comply with the requirements of notationality. Thus in Goodman's scheme, any reference to a correspondence between a picture and what it pictures is omitted. This he believes is 'corrective'. It may be that picture making and interpreting are not the straightforward processes that they at first may seem to be. However, denying the participation of any sort of resemblance in depiction, even though it may defy a simple and tidy formulation, is I believe throwing away a very useful concept. Penrice (1980 p203), commenting on this same topic, notes that,

'There is a wry humour in the fact that a good many of those who have read Goodman's book and been persuaded by his arguments find themselves robbed of a distinction that they simply cannot do without...'
A more moderate analysis of the nature of pictorial representation is given by Umberto Eco, who allows that in certain cases 'iconic signs' may be 'motivated' by what they refer to.
Eco's (1976) critique is contained in A theory of semiotics. His (op cit p48) theory rests on the notion of a 'sign-function', which is the correlation between an expression and a content, based on a conventionally established code. This system of correlation provides the rules which generate sign-functions.

Eco points out that if signs exist which are 'motivated by, similar to, naturally linked with their object' then the theory of a sign-function as outlined above should be no longer tenable unless the signs also involve some sort of cultural correlation. He acknowledges that the modes of correlation are different for words and images, but maintains that the latter, like the former, are conventionally coded without asserting that they are totally arbitrary. This requires a more flexible sense to the term 'convention', which Eco regards as coextensive with 'cultural-link' but not coextensive with 'arbitrary-link'[8]. In order to allow for the operation of a 'cultural mode of correlation' in the way images signify, Eco (op cit p191) challenges 'some naive notions'. These are that 'the a so-called iconic sign:
1 has the same properties as;
2 is similar to;
3 is analogous to;
4 is motivated by its object'.
Also challenged are the contrasting notions that 'the so-called iconic signs:
5 are arbitrarily coded...
6 ...may be subject to multiple articulation, as are verbal signs'.

With regard to these 'six naive notions', a brief summary of some of Eco's views will be given.

Eco (op cit p192) points out that the notion of an iconic sign having the same properties as its object is somewhat tautological.
It could for instance amount to saying that,
'
the true and complete iconic sign of Queen Elizabeth
is not Annigoni's portrait but the Queen herself (or
a possible science fiction dopplegänger)'.

Eco's rejection of this idea is similar to Goodman's (op
cit) dismissal of the 'copy theory' of representation.

Eco (op cit p196) allows that 'similitude' is more precise
and may mean that two figures are alike in all respects
except size. More exactly it can be defined as,
'
the property shared by two figures that have equal
angles and sides that are proportionally equivalent.'

He points out that there is also the similarity which
arises when only topological relations, or relations of
order, are preserved at the expense of others.
'
Both geometrical similitude and topological
isomorphism are a sort of transformation by which a
point in the effective space of the expression is
made to correspond to a point in the virtual space
of a content model.' (op cit p199)

Such transformations are transformations 'in the technical
sense of the term', presumably as it is used in
mathematics. Eco, then, distinguishes between those
transformations which preserve metric properties and others
which preserve topological properties.

Geometrical perspective is also a mathematical
transformation, which maps from three-dimensions into
two-dimensions. This projection preserves topological
relations whilst varying metric properties, not in an
arbitrary way, but rather according to the precise rules of
the transformation. Given this, and the importance of
perspective in the history of representation, it is notable
that nowhere in Eco's book is this topic specifically dealt
with. This is especially surprising as other commentators
have alluded to the 'naturalness' of perspective. But for
Eco (op cit p200)
'
a transformation does not suggest the idea of
natural correspondence; it is rather the
consequence of rules and artifice.'
Eco rejects analogy as an unverifiable category if it is taken to mean a sort of native or mysterious parenthood between images and portrayed things. However, if analogy is understood in the only sense that is verifiable, as a system of proportional relations, then it is acceptable. This is the theoretical basis for the operation of analogical computers. However, in this sense, analogy is the same as similarity and does not exclude cultural convention.

In semiotic theorizing the term 'motivation' is applied to the process whereby a sign or expression is somehow shaped by what it refers to. Various phenomena which are apparently motivated images, such as specular reflections, duplicative replicas, etc are discounted by Eco (op cit p201) as having nothing to do with signification in terms of his semiotic theory. With regard to iconism and convention Eco (op cit p204) stresses that:

'...to say that a certain image is similar to something else does not eliminate the fact that similarity is also a matter of cultural convention...similarity does not concern the relationship between the image and its object but that between the image and a previously culturalized content.'

He (op cit p206) presumes the existence of recognition codes. The recognizability of the iconic sign depends on the selection of pertinent features of the content, but these must be expressed.

'Therefore there must be an **iconic code** which establishes the equivalence between a certain graphic device and a pertinent feature of the recognition code.'

So whilst certain signs make use of a kind of similarity, it is nevertheless bound up with convention. This conventionality is not synonymous with arbitrariness, as motivation also occurs. Although ruled by convention, Eco maintains that iconic signs are not subject to multiple
articulation as are verbal signs. He (op cit p215) asserts that,

'...anything taken as an iconic sign must be viewed as: (a) a visual text which is (b) not further analyzable either into signs or into figurae.'

He (op cit p16) goes on:

'...The units composing an iconic text are established - if at all - by context. Out of context these so-called "signs" are not signs at all because they are neither coded nor possess any resemblance to anything.'

Eco (ibid) concludes his critique of iconism:

'Thus iconic signs are partially ruled by convention but are at the same time motivated; some refer to an established stylistic rule, while others appear to propose a new rule...iconism is not a single phenomenon, nor indeed a uniquely semiotic one.'

So, unlike Goodman's case, Eco's critique is not an out-and-out rejection of iconism. Indeed Eco (op cit p257) notes that,

'in the case of projections...the so called "scales of iconism" can be accepted as heuristically useful.'

As already noted, perspective as such is not mentioned by Eco. Goodman deals with it in some detail, dismissing it as mere arbitrary convention. On the other hand, perspective is a central feature in Hagen's theory of pictorial perception, considered next.
Hagen (1980 b) outlines her generative theory of perception, particularly as it relates to pictorial representation, in Chapter 1 of *The perception of pictures*, Volume 2. The chapter also contains a useful presentation and critique of positions held by the principal theorists on the nature of picturing. Hagen takes as part of her theory the notion of 'invariance'. This is that, across a family of perspectives, there are invariants of structure in the light specific to the scene viewed and the movement which produced the various projections. Hagen argues that formal analysis shows the existence of such invariants and that there is strong empirical support for believing they are used in perceptual processes. However, because picking up invariant information in light does not allow one to identify unknown objects, recognise instances of projective ambiguity, or participate in mental rotation experiments successfully [9], Hagen believes something else is needed as an explanation of successful perception. Hagen (op cit p28) points out that the context of non-change is change and the generative theory she proposes considers both momentary and invariant appearance equally.

'Both change and non-change, variants and invariants, are equally specified by the natural perspective [10] available to the moving observer (and the stationary observer in an environment undergoing local transformation through object movement). It follows then, that a comprehensive theory should conceive of visual perception as consisting of three interrelated components: first, the ability to pick up the formless and timeless invariants which specify the permanent properties of objects and events; second, the ability to attend to and indeed generate momentary perspective appearances of objects and events which specify the variant properties; and, third, an awareness of the rule or generator of these invariant and variant aspects operating as a conjunction of the permanent
properties of the object and the geometrical transformations it can undergo. The entire family of possible perspective views of an object is as generated by rule as the invariant information of the object persistent across its members.'

Hagen argues, then, that the generative rule enables an observer to recognise any single perspective aspect of say, a cube, as one instance of all its possible transformations (see Figure 4-9).

Projective ambiguity, already mentioned (see Figure 4-6), is easily resolved by the motion of the observer, except of course in the case of pictures. However Hagen (op cit p29) believes that,

'notwithstanding this...the generative function provides a basis for asserting structural equivalence between perspectivist art and reality.'

If variant and invariant components of optical information are available to any adult perceiver, they are consequently available to any artist in any culture. Hagen asserts that natural perspective is the common source for all representational styles of picturing. They differ in only three major perceptual ways.

The first of these is of most interest here and concerns the question of where the artist stands relative to the depicted scene and which momentary appearances are depicted. There are a number of options including the traditional western solution of a single station point. An artist may also choose multiple station points which may be frontal, eccentric, near, far, or any combination of these. Hagen (op cit p30) says that,

'There is nothing in the perceptual process itself to restrict this choice and each option is perfectly consistent with the existence of natural perspective. The pictures produced by each choice share the common geometrical core of natural perspective, each is perceptually "truthful" and
non-conventional in its depiction of the momentary appearance of things.'

Whilst there are no perceptual restrictions to the options, there are indeed cultural ones determining the selection of the mode of depiction used. Hagen suggests that we have been misled frequently into believing that the resulting pictures are themselves conventional, but she firmly rejects this.

Hagen gives an example of the so called 'split-style' art of the Indians from the North West coast of America. This style of representation results when two or more distant viewpoints are taken for a single object. In the specimen shown in Figure 4-10 Hagen (op cit p30) points out that the design,

'clearly presents to the viewer more than the single aspect available from the single station point...and [that] the organization of the body parts retains organic logic if not photographic fidelity.'

She does not suggest that such depictions are determined solely by the consistent application of geometry, which of course is also true of any developed art style.

I might observe here that depictions which show impossible views have been characterized as drawings of what is known rather than what is seen. Children, for example, sometimes draw both end elevations of a house attached to either end of the front elevation. Hagen's theory seems to offer an alternative way of considering such pictures, if we can suppress our deeply engrained single viewpoint criterion for judging realistic representations. I also notice that the multiviewpoint depictions have much in common with the 'development drawings' used by designers of structures made out of flat sheets (see Figure 4-11). These drawings represent the outline pattern of the material after cutting out and before folding into the three dimensional form. This is, in a sense, the reverse of the process of creating a split-style representation.
Our familiarity with depiction of scenes from a single point apparently 'masks the kinship of the modern Western system with the parallel perspective so common in Japanese art', which often uses more than one eccentric viewpoint placed at 'optical infinity'. Optical infinity is defined by Hagen (op cit p32) as 'the distance beyond which perspective diminution across an object becomes either indiscernible or trivial.'

I notice that this Japanese style of depiction seems very similar to the geometrically formalized system called 'oblique projection' (British Standards Institute 1969), which will be reintroduced towards the end of this chapter.

The second of Hagen's major perceptual characteristic is the relative emphasis on variant versus invariant features of the scene chosen. This again seems to be a question of 'characteristic views', which Goodman dismissed as impossible to specify. Characteristic views contain invariant structural information for the permanent properties of the objects viewed. Arnheim (Hagen op cit p35) apparently called these, views with renvois.

'To argue that the successful representational artist must choose to depict aspects with renvois sounds at worst magical, and, at best, intuitive...[but] however magical or intuitive the notion of renvois is at present, it is probably true.'

When I consider Figure 4-3 I must agree.

The third category in Hagen's (op cit p40) taxonomy of distinguishing characteristics in painting styles concerns the interplay between two and three-dimensions.

'What might be called the depiction of volume versus the creation of pattern.'

Hagen (op cit p41) summarizes as follows:

'The Generative theory of perception, emphasizing as it does the projectively rule governed commonality of both structural invariants and momentary variants in the light coming to the eye, anchoring both in
natural perspective, lays the foundation for a
descriptively adequate theory of representation.
The three-point organization framework provided by
(a) selection of the station point option, (b)
relative weighting of variants and invariants, and
(c) balance between two- and three-dimensional
pictorial components, provides a system for
cataloguing all representational art perceptually
with critical attention to the perceptual
similarities and differences among them.
Consideration of pictures within such a framework
should convince the observer that differences in
representational style from picture to picture are
perceptually trivial, no matter how great the
aesthetic differences may be.
Goodman shows us that the definition of realistic representation is perhaps not so straightforward as we might at first suspect. His proposals for a system of analysis based on the concept of notationality may well have value in dealing with symbolic systems of signification. However, in any theory of picturing, it not only seems counter-intuitive to disregard correspondences between images and the scenes they depict, but wrong. This can be concluded if one accepts the evidence and analysis given by others, especially Hagen. Goodman's (op cit p46) insistence that,

'no degree of similarity is required between even the most literal picture and what it represents'

is not acceptable, in particular his arguments for the inadequacies of perspective have been shown to be ill-founded.

Eco takes a more moderate line, pointing out that while certain sorts of similarity may play a part in picturing, they do so by means of cultural conventions. These determine what features of a given object are pertinent and the transformational process by which they are represented. Presumably the preservation of the culturally determined pertinent features becomes more crucial with increases in the degree of impoverishment of the representational image. Eco (op cit p216) notes, on the other hand, that in some cases,

'the constitution of similitude seems to be more firmly linked to the basic mechanisms of perception than explicit cultural habit.'

Hagen re-establishes natural perspective to a central position in her generative theory of perception, a theory which is creative in character. She (op cit P44) claims it provides for a,

'determinate precept given by the deductive laws of ecological geometry.'
Hagen (op cit p45) points out that there are no formal differences between a viewer rotating around a static object, or a static observer viewing a rotating object. The transformation is the same, residing in the object/viewer relation, and the meaning of the event resides in this relation.

'The meaning is not given by the head to an unstructured stimulus, nor is it given by the stimulus to the unstructured head. The relation between the two is reciprocal and symmetrical.'

In the text quoted, Hagen attempts to show the utility of the generative function as a general theory of perception. She does this by illustrating its descriptive adequacy as a theory of representation. If one accepts the foregoing arguments for the role of natural perspective in perception, then clearly it follows that it must also play a central role in pictorial depiction for all cultures. This use of natural perspective, when depicting scenes, requires the flexibility of assuming multiple, eccentric and far distant points of observation. Given this flexibility, Hagen's theory can account for the diverse styles of representing three-dimensional space. It also establishes their common origin in perception. Some of the constituent varieties of projection from which scenes could be composed have been formalized and categorized. Figure 4-12 shows these arranged in a family tree, adapted from one shown in British Standards (1969 p61). The adaptation includes examples of the visual effects of each projection.

It will be clear from the preceding comments that the Hagen theory coincides more or less with the position adopted for the purposes of the thesis presented here. However, it is accepted that to some extent convention plays a part in establishing similarities. With regard to this, Eco's analysis is helpful. In particular it is acknowledged that cultural convention plays a part in determining what aspects of an object or event are pertinent and must, consequently, be depicted for recognition to take place.
It is the function of diagrams to depict certain pertinent features of their objects. Where these features are tangible, then the diagrams tend to be 'literal'. The diagram and the diagrammed are in some respects similar. The nature of this similarity, between literal diagrams and their objects, will be examined in the next chapter.
Summary

Some of Goodman's (1976) views have been put forward, concerning his rejection of what he suggests are commonly held ideas about a relation between resemblance and pictorial representation. Goodman takes the view that such notions as similarity, or imitation, play no part in establishing what a picture depicts. Some counter arguments were introduced. Goodman also rejects perspective as any measure of image fidelity and this view was challenged.

Eco's (1976) critique of iconism was outlined. Eco believes that while convention plays a role in correlating iconic signs with their content, they are at the same time motivated.

Hagen's (1980 b) generative theory of picture perception was described and this relies heavily on the concept of 'natural perspective'.

The position adopted for this present work was stated. Basically it coincides more or less with Hagen's, but it is acknowledged that convention plays a role in picturing.
5.1 Literal correspondence

5.2 Semi-literal correspondence

5.3 Non-literal correspondence

Summary
5.1 Literal correspondence

It was pointed out towards the end of section 3.5 in Chapter 3, that the semiotic levels of pragmatics, semantics, and syntactics give the main categories under which diagrams are interpreted by their readers. These categories relate to the modes of correspondence, depiction, and organization. These have been nominated in this dissertation as being the principal variables available for the design of diagrams. The pragmatic level relates to the,

**mode of correspondence**

which is concerned with the relationship between a content model and what it represents. The mode of correspondence may be, more or less,

**literal.**

The etymology of 'literal' is disputed but it is probable that its Latin root *littra* first meant a mark made on parchment and then the reading of the mark. Thus literal means having to do with a letter of the alphabet, hence: 'according to the letter; adhering to the actual words; not fanciful, metaphorical etc' (Wyld nd). By extension the term has come to mean: 'Adhering to actual fact, perfectly accurate' (ibid). It is in this latter sense that the term is used in this dissertation, although its origins may also serve to point up the suggested relation between speech and diagrams.

It was argued in Chapter 4 that there is a useful sense in which pictures can be said to be similar in some respects to the scenes they depict. It is accepted that convention mediates to a degree in the process which correlates the two but, nevertheless, there are certain ways in which the thing pictured can be said to determine certain aspects of the picture. In the case of diagrams, what is pictured is the content model. It is proposed that any diagram is similar to its content model, whether the model is apparently flat and lying in the plane of the picture, or
whether parts of it seem to be depicted as occupying some three-dimensional space, as it were, beyond the picture. In this case some form of projection is used, such as one of those shown in Figure 4-12 of Chapter 4. In any case the mode of correspondence is not concerned with the relation between the diagram as a picture and the content model it pictures. Rather it is concerned with the relation between the content model and what it represents. The content model comprises significant elements. A significant element and the thing it represents may have the same texture and colour, and may share certain geometrical properties. These can range from congruency, through similarity, to topological isomorphism. The more of these correlations there are between significant elements and that which is represented, the more literal is the mode of correspondence. It should be noted that sometimes it will be convenient to talk of the mode of correspondence of a grammatical space, or even of the content model as a whole, rather than that of the significant element or elements they may contain.

Concepts, such as hierarchy, by their nature are not susceptible to a literal mode of correspondence and this necessarily restricts the mode of correspondence to the non-literal.

It is also possible for real objects to be represented in diagrams by content models which are in some degree non-literal.

In order to make these designations clearer I shall now give some examples. First the literal mode of correspondence will be considered.

Let us look at Figure 5-1. This shows various pieces of machine tool equipment laid out as they would be when carrying out various manufacturing operations on castings. The rough castings commence processing at the two starting points shown at the bottom left of the diagram and are carried to the various machines for turning, drilling,
Figure 5-1
From: Staveley Machine Tools catalogue
grinding, etc, by means of interconnecting conveyor apparatus. The products finish their processing at the machines shown at the top right of the diagram.

The illustration was actually completed before the equipment was installed [1]. The drawing was laid out using the grid underlay, shown in Figure 5-2, to ensure perspective fidelity. Technical accuracy of the proposed equipment was achieved by referring to photographs of individual machines of the same type, and the positioning of the various items was based on a draughtsman's layout of the proposed factory.

Even after installation an aerial photograph would be virtually impossible without removing the walls, roof, overhead power supply, and ventilation ducts from the factory building. Nevertheless, if this were possible, I would expect the perspective projection produced by an appropriately taken photograph to show a high degree of correspondence to the spatial arrangement depicted in the drawn illustration. We take the content model depicted in the diagram to closely approach congruency, in the geometric sense, with the situation represented. Whether such a situation actually exists somewhere in the real world, or merely could exist, is of no consequence. If the scene depicted is possible, and if it is intended that the diagram represents that possibility, then the classification of literal applies. We have what is sometimes termed a 'realistic picture'. The scene is to be taken at face value as it were, unlike, say, the taxonomical tree shown in Figure 3-12 of Chapter 3.

Let us return for a moment to the proposal, made in Chapter 3, to classify the various spaces of a diagram in terms of their grammatical functions. In the case of Figure 5-1, does it make sense to speak of subject and predicate space? We could say that any machine which comes under our consideration becomes a subject and any spatial relation to any other, such as being next to, taller than, or a different shape from, is contained within the
predicate space. But all the various elements in the content model are shown as contemporaneous and occupying a single continuous space. Following the spatial character of the proposed grammatical taxonomy, we can say that in this case all the subject and predicate spaces, and, consequently, all the noun and verb spaces, are coextensive.

So we have a diagram which uses a literal mode of correspondence to represent a coextensive space. According to some definitions we would not have a diagram at all (cf Maldonado 1961 Chapter 1). However, I have argued that the function of a diagram is to use its spatiality to represent relations. These relations themselves may be spatial. For a picture to qualify as a diagram is, then, a matter of use rather than something intrinsic to the particular display or what it refers to. If Figure 5-1 is used to show the sequence of machines in the process of production, I would say it is as much a diagram as any highly schematized flow chart, such as shown in Figure 5-3, which in fact shows the same production line. In any event, hard and fast distinctions between diagrams and non-diagrams based on the mode of correspondence are impossible; many diagrams have some elements which do not resemble the things they represent in a literal manner, but which interact with yet other elements which do show such resemblance.

Also, the mode of correspondence is not necessarily simply literal or non-literal. It should, rather, be thought of as a position on a continuum between these two extremes. For convenience of description I will term the general area about the midpoint of the continuum **semi-literal**.

It must be stressed that this should not be taken to mean any absolute position. The idea of there being a continuum of this sort is also explored by Nagasaw (1981 p11).

"The transition from the representation of the "physical" to the "spiritual" does not necessarily run parallel with concepts of "tangible" to "intangible"; between the extremes of black and white, there are many shades of grey."

See Figure 5-4.
Figure 5-3
From: Staveley Machine Tools catalogue
What it means to speak of a significant element, or group of elements, having a semi-literal mode of correspondence, will be dealt with next.
Let us imagine a small workshop which contains one each of a small number of different machines. A diagram could be made which shows the layout of this workshop in a style similar to that of Figure 5-1. Instead of a perspective projection of the workshop, an axonometric view might have been chosen; that is, with the observer's eye removed to infinity and the plane of projection so arranged as to be perpendicular to the projectors which are of course parallel to each other. We would still have a literal mode of correspondence in all respects. Fidelity to station point perspective in the diagram is not required for the classification of literal, which anyway concerns the relation between the content model and the things referred to, not the content model and picture.

Let us further suppose that we can select a side view so that the projection plane is exactly vertical, and no machine conceals another. With an axonometric projection we will not get an accelerated foreshortening effect in the more distant machines. In fact all scale distances above the ground will be preserved. So, if we wished to make a diagram for, say, comparing the heights of the various machines, we might, as it were, move the images closer together whilst maintaining a constant ground line. Such a diagram is shown in Figure 5-5. It will be seen that the images are much simplified, the mode of depiction being almost that of a silhouette. Mode of depiction is another important variable available to the diagram maker and this will be dealt with later in Chapter 7. Additionally we have rotated each machine so that its principal planes are square to the picture. In fact we have not moved the machines themselves at all, neither have the images in the diagram actually been adjusted. I propose that if any manipulations have been carried out at all they have been applied to what I have called the content model, which in the case in question is now no longer literal in all respects. The noun spaces are literal but not
coextensive. The verb space, that is the space which unites the various machines, is literal in terms of height but not in terms of location on the ground. So the different dimensions of the verb space may vary in their modes of correspondence. We may say then that in Figure 5-5 the verb space is to some degree semi-literal while the noun spaces are literal.

If the modes of resemblance between the various noun spaces of the content model are all literal, one might question what it means to say that the verb space is also literal with regard to the heights of the machines. Am I not simply using different names to describe the same thing? This is not the case. The verb space may be distorted in such a way as to show all the machines at a similar size, quite independently of their actual dimensions, but each to its own scale and proportionally correct. Such a diagram might be used to indicate comparative shapes at the expense of relative magnitudes. The mode of correspondence between the noun spaces and the things they represent would remain literal. However, the verb space uniting the various machines would no longer be literal in any dimension.

Let us now consider a situation where both noun and verb spaces are semi-literal to some extent.

William Playfair is credited with the first published appearance of the statistical bar chart in his Commercial and political atlas of 1786 (Beniger and Robyn 1978 p3). This chart is shown here in Figure 5-6. I should make the incidental observation here that Oresme had proposed the use of the graphic representation of two related variables in the year 1350, using illustrations I would not hesitate to call bar charts. An example of one of Oresme's charts is shown in Figure 5-7. However, it seems that these charts are entirely theoretical and apparently do not represent any empirical data, but rather show how such data might appear [2]. It would seem that Playfair was first in the use of bar charts to express actual statistical data.

In the third edition of the Commercial and political atlas

[2] Funkhouser (1937 pp274-277) describes these charts which are contained in the Tractatus de latitudinibus formarum written about 1350.
Figure 5-6
From: Playfair
(Beniger and Robyn 1978 p3)

Figure 5-8
Drawn by Sue Hyne in 1981

PUBLIC SPENDING PER POUND IN 1974

Categories:
- Education
- Health and Personal Social Services
- Defence
- Housing
- Defence
- Social Security
- Miscellaneous Social Services
- Other Services
- Roads
- Law and Order
- Agriculture, Fisheries and Forestry
- Home Affairs
published in 1801, Playfair (see Funkhouser 1937 p281) describes a bar chart in the following manner:

'Suppose the money received by a man in trade were all in guineas, and that every evening he made a single pile of all the guineas received during that day, each pile would represent a day, and its height would be proportioned to the receipts of that day; so that by this plain operation, time, proportion, and amount, would all be physically combined.

Lineal arithmetic then, it may be averred, is nothing more than those piles of guineas represented on paper, and on a small scale, in which an inch (suppose) represents the thickness of five millions of guineas,...'

Lineal arithmetic is Playfair's term for the graphic representation of statistical data. The idea of a bar chart resembling piles of coins is fairly explicitly presented in the diagram shown in Figure 5-8.

In Playfair's example, each day is represented by a pile of similar coins, although this would not be a literal picture of the takings. These might come in coins of various denominations and even promissory notes. In any event a tradesman would not normally stack his daily takings in a single pile. However, it would be possible to convert the takings into bank notes or coins all of the same denomination and it would be possible to pile them into a single column. In this case we could say that the mode of correspondence between the noun space of a single column of money in the content model, and the actual takings for the day in question, is neither literal or non-literal. It must be nearer the semi-literal region, being, as it were, somewhat contrived yet physically possible. In this respect the operation of stacking the coins is similar to moving the machine tools closer together in the previous example, the better to judge their relative heights. Possible if not actual.
Each separate day is shown by the relative positions of the piles of coins. For example, Tuesday might be to the right of Monday and to the left of Wednesday. Such a spatial arrangement is in no way a literal picture of the way one trading day follows the next. The dimensions of the verb space representing the sequence of days is then non-literal.

Semi-literal correspondence is where we do not expect the content model, or some part of the content model in question, to have a high degree of correlation with the objects represented. Nevertheless it should be at least possible to envisage some spatial rearrangement of these objects which matches the content model, whilst leaving some significant observable correspondence between the rearranged objects and their original state.

The use of the term semi-literal also includes those instances where some special measure would have to be taken in order to make some physical phenomenon visible. Examples of this could include traces of selected light rays (Figure 5-9), the locus of a point on a rolling wheel (Figure 5-10), or the flight path of an insect (Figure 5-11). An instance of the practical realization of such theoretical visualizations is the photograph of traces made by charged particles in a bubble chamber (Figure 5-12). This idea can also apply to the mapping of fields, such as in a diagram showing the areas of Europe affected by rabies, or to the visualizing of volumes, as in Figure 5-13 which shows a fish's window of vision.

Various techniques are used by technical illustrators for making the hidden visible and these include exploding, ghosting and cutting-away. All these are shown in Figure 5-14.

Having considered the semi-literal let us now look at the non-literal.
5.3 Non-literal correspondence

In Figure 5-5 the machines of a particular workshop are represented in terms of their general outline and their relative sizes. The content model varies from the actual content, in this case a hypothetical machine shop, in that the spatial relations between the machines have been changed. Such distortions need not be uniform, or indeed confined to a single plane or even a single dimension of a grammatical space. In Figure 5-5 these transformations are merely an organizational convenience with no particular significance being attached to them. They are, as it were, diagrammatically neutral. However, such spatial re-arrangements can be imbued with meaning.

Figure 5-15 is a good example of this and shows a time-travel map of Britain. The verb space in the content model gives the relation between the marker representing London and other markers. This space has been arranged to form an analogue of the time taken to travel from London, by the fastest mode of public transport, to the places the other markers represent. Here noun and verb spaces seem closely related but they can be distinguished. We will consider noun spaces first.

Whilst the markers are not literal pictures of the places they represent, they cannot be classed as entirely non-literal. In fact they have the minimal degree of resemblance to any physical object that is possible. The nature of the correspondence is at the highest level of generality in that both the spots and the places they represent have some shape, size, etc. In short, the markers resemble the places they represent to the extent that they exist in some space.

However, the verb space is quite literal in terms of direction from London and would match a set of compass bearings taken from the capital.
It is non-literal in other respects because the distances from London to other places, as portrayed in the content model, represent amounts of time, and of course time cannot be pictured in a literal manner.

With regard to our perceptions of time, Köhler (1930 p125) tells us that,

'As we experience time, it has some properties in common with space, particularly with one dimension of it, namely its sagittal axis with man as the centre. Therefore, words referring to relations on this axis are used as terms for temporal relations everywhere and in all languages. In English we have something "before" or "behind" us in both meanings; we look "forward" in space as in time, and death will come "nearer" in time, as one place is nearer to me in space than another.'

In this connection Funkhouser (1937 p279) notes that,

'It is difficult to say at what period it first occurred to someone to think of time as a line extending before him indefinitely in either direction with the events of history appearing as points on the line and with an event of some duration represented by the distance between two points.'

When considering time 'it is almost irresistible to think either in terms of its flowing or of our moving through it' (Flew 1979 p310). Movement through space and the progress of time are closely associated for us and seem inseparable in the real world. However, in diagrams one can show directly only the spatial component of this duo.

Distance is, as it were, a kind of metaphor for time, and in the case of Figure 5-15 the two seem closely related. If there were a distinct border between the semi-literal and the non-literal, one might be tempted to say that the verb space here is close to it in terms of this space-for-time metaphor. To me space and time do not seem quite so closely related in the next example.
Let us imagine a workshop which happens to contain one each of the various machines produced by Miyano during its history since 1948, and let us suppose that these machines are laid out according to the requirements of production. A diagram could be made which shows this layout in a fashion similar to that used in Figure 5-1. The subject and predicate spaces would be coextensive and literal. Suppose one then took that diagram and cut out the images of the various separate machines and composed a new diagram. The distance on the new diagram from an image of a particular machine and some datum line, say the bottom edge of the paper, could be adjusted to be significant in some sense. It could be an analogue of the time elapsed from the commencement of machine tool manufacture in 1948 to the appearance on the market of the particular machine represented by the image. In this respect the new diagram would be similar to Figure 3-9 in Chapter 3. The noun spaces of the individual machines would still be literal but no longer coextensive. One of the dimensions of the new verb space surrounding the machines would represent time. This reorganized verb space would now be non-literal, as it is in the time dimensions of the verb space of Figure 5-15. In the present case, however, the time represented would be a particular period of past history and would not be associated necessarily with any journeys. In this respect the metaphor of space standing for time seems to me somewhat further removed than in Figure 5-15.

It is of relevance to recall here the extent to which spatial metaphors are used in speech, as in the last sentence where I spoke of one metaphor being 'further removed' than another. Also we may speak of some word being 'closer' to some meaning than another, and of life having its 'ups' and 'downs' as if time's 'sagittal axis' formed a wave pattern like the display of an oscilloscope.

I have already quoted, in the first section of Chapter 3, Shepard's (1975) observation that speech is often supplemented by gestures. It seems to me that many such gestures have a diagrammatic quality. For example, a
colleague of mine recently completed the sentence:

'The British public's voting habits are...' with a snake-like movement of his hand. I took the forward motion to represent the process of time and the side to side movement to mean the switching of political allegiance. He drew, as it were, a transient diagram in the air. It did not correspond in a literal way to the suggested political vacillations of the voters; rather, I would argue, it took its meaning from our common experience of the real world and was a kind of spatial metaphor. I would further suggest that this kind of spatial metaphor is the principal means by which all non-literal diagrams take their fundamental meaning. It might be thought that my colleague's gesture was simply an imitation of a graphic diagram, and that this was the origin of its meaning, as opposed to the notion that such gestures, and their sources, are the inspiration for diagrams. I believe that we do in fact imitate diagrams, but usually these imitations are either drawn invisibly with a finger on a table, or else traced in the air in a vertical plane. In the case in question the movement was forward through a horizontal plane and I believe its inspiration was from direct experience of common phenomena, such as the movement of animals or even the flowing of rivers.

In the light of this it is appropriate to consider the nature of metaphor in the next chapter.
The concept of the content model has been developed through describing its various modes of correspondence with what a diagram represents. This relation is to be thought of as a continuum. The terms literal, semi-literal and non-literal were proposed to denote points on that continuum. They can be used to refer either to the content model as a whole, or to its various grammatical spaces separately. In the case of what are sometimes termed 'realistic pictures', all the grammatical spaces are coextensive and literal.

There are semi-literal elements in a diagram when we do not expect a high degree of congruency between the content model and the things to which it refers, or when some special measures would have to be taken to observe in the real world what is depicted in the diagram.

Diagrams, or parts of diagrams, which refer to intangibles have, of necessity, a mode of correspondence which is non-literal, although of course this does not necessarily preclude the use of the non-literal mode when one is representing real objects.

It was argued that the principal type of non-literal correspondence might be said to operate metaphorically.
Chapter 6  METAPHOR IN DIAGRAMS

6.1 Metaphor in language
6.2 The nature of metaphor in diagrams
6.3 The value of metaphor in diagrams
6.4 Convention and metaphor in diagrams
6.5 Rhetoric in diagrams
6.6 Mnemonic diagrams

Summary
Before looking at the relation of metaphor to diagrams it will be useful, perhaps, to look at one or two studies of metaphor as it relates to the spoken and written word.

In the *Universal dictionary of the English Language* (Wyld nd) a metaphor is defined as a,

'Figure of speech in which a word or phrase is used to denote or describe something entirely different from the object, idea, action, or quality which it primarily and usually expresses, thus suggesting resemblance or analogy: the curtain of night; the ocean of life; "My heart leaps up when I behold a rainbow in the sky" (Wordsworth); all nature smiled.'

This suggests a transference or carrying over of usage and indeed '-phore' represents the Greek – *phoros*, which means carrying. The prefix 'meta-' which is often used to express change is from the Greek *meta*, meaning: among, between, after, beyond.

Wheelwright (1962 p72) proposes two principal aspects of the process of metaphor, one concerned with the idea of 'semantic motion' and the other with 'combining'. These he identifies by the names 'epiphor' and 'diaphor'.

'The word "epiphor" is taken from Aristotle, who says in the *Poetics* that metaphor is the "transference (epiphora) of a name [from that which it usually denotes] to some other object".'

'Diaphor', Wheelwright (op cit p74) concedes, is the less conspicuous of the two elements of metaphor and is concerned with "...producing new meaning by juxtaposition alone, (op cit p78). He (ibid) gives the word combinations of Gertrude Stein as examples of striving towards the purely diaphoric:
"Toasted Susie is my ice-cream", and "A silence a whole waste of a desert spoon, a whole waste of any little shaving...".'

Although there may be an element of something akin to diaphor in some diagrams, the principal interest here is with the more traditional idea of transference of usage from one domain to another. Wheelwright (op cit p73) develops this concept as follows:

'Since the essential mark of epiphor - which is to say, metaphor in the conventional Aristotelian sense - is to express a similarity between something relatively well known or concretely known, (the semantic vehicle) and something which, although of greater worth or importance, is less known or more obscurely known (the semantic tenor), and since it must make its point by means of words, it follows that an epiphor presupposes a vehicular image or notion that can readily be understood when indicated by a suitable word or phrase. In short, there must be a literal base of operations to start from.'

These features are of key importance to the assertion in my thesis that there is a parallel between the operation of metaphors and the functioning of non-literal diagrams. This parallel will be returned to after a little more discussion concerning metaphors.

The traditional Aristotelian notion of metaphor is couched in modern academic terminology by Henle (1958 p173 ff) who says:

'A sign is metaphorical if it is used in reference to an object which it does not denote literally, but which has certain properties that its literal denotandum has.'

These 'certain properties' which, as Wheelwright (op cit p73) says, 'express a similarity' are generally thought to provide the relational basis, or 'ground' for the metaphor. So we have the terms, 'tenor', 'vehicle', and 'ground'
when dealing with metaphors. Borrowing an illustration from Tourangeau and Sternberg (1981 p28) we may say that in the metaphor, 'jealousy is a green-eyed monster', jealousy is the tenor, green-eyed monster is the vehicle, and the shared category of being a destructive force is the ground. So in the traditional view of metaphor the tenor and vehicle must have some common attributes. A summary of Tourangeau and Sternberg's (op cit) work on metaphor will be useful as it contains much of relevance to the thesis presented here. They (op cit p28) point out that thus stated this view is subject to criticism as,

'features that are part of the ground of the metaphor are often not shared by the tenor and the vehicle, and features that are shared are often not part of the ground.'

They illustrate this point by the example, 'men are wolves', where both tenor and vehicle share many characteristics, eg 'both live on land, both are animals, both are (or can be) nomadic'. However, none of these shared characteristics is relevant to the ground of the metaphor. They point out that,

'Shared category membership is too powerful a device for interpreting metaphors. There is always some category to which two terms belong; there is not always some reasonable interpretation of a metaphor.'

What is relevant in the example given above is that we can see both men and wolves as predatory. However, this feature is not literally shared. Predacity applied to men means something different from predacity in wolves. At best there is only some sort of correspondence as they are predatory in different ways.

Reviewing some recent reformulations of the nature of metaphor, which are generally consistent with their own ideas, Tourangeau and Sternberg (op cit p29) report the argument that 'a natural asymmetry is suggested between the tenor and the vehicle' as 'salient features of the vehicle...are linked to nonsalient features of the tenor'.

6/3
Also, attributes of tenor and vehicle cannot often match exactly because of 'domain incongruence'. This is because 'terms...from different domains and their attributes are limited to those domains...[eg] Outside the realm of colour, green loses its ordinary meaning.'

It is assumed that,
'...similarity between terms is based on resemblance, rather than identities, between features of tenor and vehicle. Specific types of features may be implicated in nonliteral similarity...'

In the view of Tourangeau and Sternberg (op cit p30),
'...the features that play a special role in the interpretation of a metaphor are those that are most critical to locating the relative position of tenor and vehicle within their respective domains.'

For example one might say that both an eagle and Mrs Thatcher occupy similar positions in terms of prestige within their respective domains of birds and world leaders. These domains are incongruent but have features which are similar although not necessarily identical.

Tourangeau and Sternberg (ibid) also report that because the tenor is viewed in terms of the vehicle, some theorists hold that one sees them in dynamic interaction and one's views of both are modified. This group tends to emphasize both the importance of differences of tenor and vehicle and the absence of features which are literally shared. When it comes to questions of aptness in metaphor,

'Interaction theorists regard similarity and differences as equally important; in our version of the interaction view, the tenor and the vehicle must be drawn from different domains, yet one must be able to see them as occupying similar "relative positions." Comparison theorists, at least in traditional formulations, emphasize similarity at the expense of dissimilarity.'

Apparently a few theorists stress incongruity as an
ingredient of good metaphors which 'jolt us out of our usual way of seeing things'. The comparison theorist, on the other hand, might say that the more similar the tenor and vehicle the better the comparison. Tourangeau and Sternberg (op cit p31) point out the theoretical weakness here that at some point the metaphor becomes 'a kind of degenerate literal statement of resemblance'. The following example is given:

"A squirrel has the face of a chipmunk" is hardly a metaphor at all; it is certainly not a good one.

The following points outline the summing-up by Tourangeau and Sternberg (op cit pp34-35) of four possible relations between tenor and vehicle which may increase aptness in metaphors:

1. Tenor and vehicle more similar (rests on the assumption that in this case comprehension is easier).

2. Tenor and vehicle dissimilar (here novelty creates a striking metaphor).

3. Tenor and vehicle neither very similar nor very dissimilar (being some complex relation of the two above).

4. Tourangeau and Sternberg's own version that a metaphor becomes more apt when:

'...tenor and vehicle are from less similar systems or domains (up to the point where correspondences between dimensions break down), and as they occupy more similar positions within their respective domains.'

Of particular interest to present concerns is the fact that they present their own version (op cit pp32-33) as a diagram depicting a 'conceptual hyperspace', shown here in Figure 6-1. Domains are points (actually shown as cubes) in this conceptual space where 'between-domain'
Figure 6-1
From: Tourangeau and Sternberg (1981 p32)

Figure 6-2
From: Tourangeau and Sternberg (1981 p33)
dissimilarity or similarity are represented respectively by more or less distance. Each point is itself a space, and these 'lower order' spaces are used to map dimensions which define 'within domain' similarities and dissimilarities (see Figure 6-2). It would seem that the subjects whom Tourangeau and Sternberg tested, in order to obtain the scalings displayed, perceived a difference between hawks and robins, partly at least in terms of degrees of aggression. This is clearly shown in the figure.

Tourangeau and Sternberg (op cit p34) suggest that, 'metaphors are better as distance within domains gets smaller. Distance between domains also has an effect. How striking or novel the metaphor seems reflects how dissimilar the domains of tenor and vehicle are.'

On this basis, 'Brezhnev was a hawk amongst world leaders' is not a bad metaphor, if one refers to the diagrams in Figures 6-1 and 6-2. Both Hawk and Brezhnev occupy broadly similar within-domain positions when power and aggression is plotted against prestige, and the between-domain distance of Birds and World Leaders is quite large.

However, as already noted, there is probably a limit to the between-domain distance, beyond which comprehensibility is affected. Tourangeau and Sternberg (ibid) comment that, 'As domains get further apart, it is harder to see correspondences between features applying within them. It is easy to see that aggressiveness in lions is like aggressiveness in eagles, harder to see that aggressiveness in political leaders is also like aggressiveness in eagles.'

They suggest that the opposed trends of greater overall similarity, and greater novelty which implies less similarity, may be combined 'to produce an inverse-U-shape relation between overall similarity and aptness' (op cit pp49-50).
They predict (ibid) that,
'...within-domain distance relates negatively to aptness and that between-domain relates positively to aptness.'

They claim that the results of their experiments support the first half of this prediction, but the evidence for the second part is weak. However, if only for the reason that the within-domain dimensions alone have a consistent effect on aptness, the within-domain and between-domain characterization of dimensions seems useful.

So far all the quoted sources have dealt with metaphor in its usual context of language. The last study has been dealt with at more length as it uses the metaphor of spatiality to represent relations of meaning, and this is presented in a diagrammatic form. The content model here is non-literal, being, as it were, a metaphor for metaphoric meaning. In a similar vein I shall be presenting, later in this dissertation, a diagram of diagrammatic interpretation. Next the use of metaphor in diagrams will be considered.
In relating metaphor to diagrams, one or two points from the preceding discussion need to be drawn out.

The relational ground between the vehicle and tenor does not necessarily consist of shared attributes. Rather, it is asserted by Tourangeau and Sternberg (op cit p29) that specific features of the terms of a metaphor have some sort of 'nonliteral similarity'. They point out that there is both 'within-domain' and 'between-domain' similarity, and that the less the between-domain distance the closer the metaphor is to becoming a 'literal statement of resemblance' (op cit p31). It is in part from these proposals that the terms

> literal
> semi-literal, and
> non-literal

have been derived to describe the modes of correspondence between the elements of the content model of a diagram and what is represented. One often finds incidences of the metaphoric being contrasted with the literal; however, the notion of degrees of metaphoricity, suggested by the idea of between-domain distance, seems useful. Hence my proposed continuum ranging from the literal to the non-literal. I make a distinction between metaphoric and non-literal which must be deal with. So far I have deferred any justification for the selection of the terms used to describe the modes of correspondence, as it seemed necessary to introduce the discussion on metaphor first. A brief explanation is now called for.

I shall assert that

> graphic metaphor

is heavily involved in many diagrams. However, I have not used the term 'metaphoric', in opposition to the term 'literal', when naming the ends of the continuum associated with the mode of correspondence. 'Non-literal' seems more appropriate for two reasons.
First it creates a more uniform set of terms and allows the introduction of 'semi-literal' as a midpoint. Secondly, the term 'metaphoric' would exclude other relational possibilities which, while not literal in character, may not be entirely metaphoric either.

Here I shall use the term 'non-literal' to apply to a super-ordinal category which includes metaphor.

Now we will look at the place of metaphor in diagrams in fairly broad terms.

It may be recalled that, when dealing with epiphor (the traditional Aristotelian metaphor), Wheelwright (op cit p73) stressed that 'there must be a literal base of operations to start from' (my emphasis). Henle (op cit) states that a metaphorical sign 'does not denote literally' but, 'has certain properties that its literal denotandum has'. It is implied then that there is a literal or, in Wheelwright's words, 'a concretely known' vehicle from which meaning may be transferred to the 'more obscurely known' tenor. In this respect metaphors are extremely useful in dealing with things which are not aspects of immediate sensory experience. As Spurgeon (1979 preface) puts it:

'Metaphors often convey to the mind truth which otherwise would not have reached understanding.'

This is especially so in connection with science:

'Science abounds in theoretical terms. "Atoms" and "molecules" are examples from physics; "ego", "super ego" and "id" are examples from psycho-analysis; "mind" from ordinary discourse. All these...refer to features of our world which are not capable of being directly observed.' (George 1964 p70)

We can only apprehend such things indirectly. Bronowski (1973 p340) tells us that,

'When we step through the gateway of the atom, we are in a world which our senses cannot experience.
...all our ways of picturing the invisible are metaphors, likenesses that we snatch from the larger world of eye, ear and touch.'

I would contend, then, that many of the diagrams of science are, at least in part, pictures of metaphors or, more precisely, pictures of metaphoric vehicles.

It seems appropriate at this point, therefore, to introduce the taxonomies of two writers who have dealt with both diagrams and metaphors. These are Peirce (1931-1958) and Knowlton (1966), whose arguments have already been dealt with, in part, in Chapter 3.

Peirce coins the term 'Hypoicon' for signs which represent their objects mainly by similarity [1]. These are subdivided into three classes:

'images',
'diagrams', and
'metaphors'

Images represent objects by a resemblance of quality; diagrams represent the relations between the parts of an object 'by analogous relations in their own parts'; while metaphors,

'represent the representative character of a representamen by representing a parallelism in something else.' (2.277)

Ayer (1968 p151) is critical of this formulation:

'A more straightforward account of metaphor would be that it drew a parallel between different objects, rather than a parallel between object and sign...'

This seems reasonable, and Ayer (ibid) goes on to point out that such a reformulation would no longer belong to Peirce's triadic classification of signs [2].

If, as I suggest, a diagram is understood to be a picture of a content model, then the meaning of a diagram is bound up in the relation between its content model and object, or
what it is that is diagrammed. This accepted, the
distinction between some diagrams and metaphors
evaporates. The notion of similarity or parallelism in
features is common to both classes of representation. This
similarity is between vehicle and tenor in the case of
metaphors, and between content model and object in the case
of diagrams. Or, if you will, some diagrams, or rather
parts of the content model of some diagrams, operate
metaphorically.

Knowlton's proposals in particular need to be reviewed, as
he sets out with similar objectives to those of the present
enterprise. On the face of it he (op cit p175) has
proposed a somewhat similar taxonomy to that of Peirce,
although Knowlton makes no reference to him.

Knowlton's scheme includes three 'logically possible types
of visual presentation' which are as follows:

- 'realistic pictures'
- 'analogical pictures'
- 'logical pictures'.

Realistic pictures are used to,

-represent some state of affairs of a sort that is
visually perceivable either directly or with
technological aid (eg, microscope, time-lapse
photography)....'

This would seem to accord with my category of a literal
mode of correspondence, and in part with Peirce's images

[3].

To illustrate the nature of analogical pictures, Knowlton
(op cit pp176-177) describes a presentation on how muscles
are attached to, and articulate bones. This presentation
includes,

-...showing a picture of the way two lumberjacks work
together to support or move a felled tree. The tree
is analogous to a bone, but is not intended to look
like bone. The two lumberjacks are analogous to a
pair of opposing muscles, but they are not intended
to look like muscles. Thus, although such an

[3] Curiously, for Peirce
2.281 photographs are not
iconic as they are 'produced
under such circumstances that
they...are physically
forced to correspond point by
point to nature'. As a
consequence of this,
photographs belong to the
second of his fundamental
divisions of signs into,
'Icons, Indices, and Symbols'.

6/12
illustration portrays objects in the visual world, these objects are portrayed only in order to show the nature of a structure or process: a process in which the portrayed objects "participate" in a manner common to the less familiar process (not so readily manifest) in the state of affairs that is of interest.'

Knowlton distinguishes between two sorts of analogical picture; those such as the example above where the content can also be exhibited in a realistic picture, and those where an analogical representation seems the only approach. He gives the example of a golfer hitting a ball, which canons off trees lining the fairway, as an illustration by analogy of what happens when a photon hits a chlorophyll molecule. The ball is the electron and the golf club is the photon.

He (ibid) sums up the distinction as follows:

'...analogical pictures can represent either the phenomenal or nonphenomenal world. In both cases this is done through the bridge of the (visual) phenomenal world.'

It is quite clear from this that by the term 'analogy' Knowlton is not referring to a system of proportional relations, but is using it as a synonym for metaphor, which is quite a common usage.

Knowlton's (op cit p178) third category is the logical picture, which is further subdivided into three types. The first is described thus:

'When "schematization" is carried to its logically furthest extreme, the elements in the state of affairs represented are represented in a totally arbitrary fashion. When this occurs, one has what is here called a logical picture: a visual representation wherein the elements are arbitrarily portrayed, while pattern and/or order of connection are isomorphic with the state of affairs represented.'
A circuit diagram for a radio receiver is given as an example of this type. To illustrate the second type of logical picture, Knowlton (ibid) asks us to consider the concepts of atom and cell. He points out that ordinarily neither is visible. However, a realistic picture of a cell can be produced by magnification of what is there,

'but a representation of the atom requires something quite different, viz., "invention"; and the result is here called a logical picture.'

Such pictures are not intended to look like atoms, but atoms are assumed to exist, unlike the referents of the third type of logical picture. In this case the referents are ideas and do not exist in any tangible form.

Although Wittgenstein is not cited by Knowlton, it should not pass without comment that the term 'logical picture' is also used by Wittgenstein (1961) in his Tractatus:

'2.18 What any picture, of whatever form, must have in common with reality, in order to be able to depict - correctly or incorrectly - in any way at all, is logical form, i.e. the form of reality.

2.181 A picture whose pictorial form is logical form is called a logical picture.'

According to Wittgenstein, pictures can be more or less rich, more or less like what they picture, but logical form is the minimum they must have in common with what they depict if they are to be pictures at all. That is, the elements of a picture must be capable of being combined in a manner such that they correspond to the elements of what is pictured. This possibility of correspondence is the logical form and, since every picture must have it, in Wittgenstein's Tractatus, every picture is a logical picture (cf Kenny 1976 p58).

However, I assume that all the logical pictures of Knowlton's scheme are distinguished from other types of picture by their high degree of schematization, although
this is only explicitly asserted for the first type where there is some isomorphic correspondence with the state of affairs represented. If the distinction is not based on the degree of schematization, it seems to me that any distinction between 'logical' and 'analogical' or even 'realistic' is hard to maintain. Even if the 'vehicle' is the subject of some invention, as in the case of the diagram of an atom, presumably the invention must have sufficient points of correspondence with the world of our experience for it to be used to represent the unknown world of the 'tenor', to use the terminology of metaphor. And surely even a logical picture takes its meaning from being in some way analogous to what is represented; that is, similar to it in a metaphoric sense, otherwise it ceases to be a picture at all. So, if the distinction rests on logical pictures being 'schematized' perhaps I can introduce the heading 'non-schematized', for other types, and be permitted to present Knowlton's scheme in the form of a matrix as shown in Figure 6-3.

Under the heading of 'Non-schematized', phenomenal objects may be represented by either realistic or analogical pictures, while non-phenomenal objects can only be shown analogically. Now it seems to me that in a classification such as this, it is the way the picture relates to what it represents which should dictate the category headings, and not the ontological status of the referent. From the taxonomist's point of view the important thing about an analogical picture is its analogical character, not that the referent may or may not belong to the phenomenal world. (The fact that certain classes of referent can only be pictured analogically may be of significance in other contexts however). Indeed, as the non-phenomenal picture types are duplicated in the phenomenal category, removing this distinction does not eliminate any of Knowlton's 'super-ordinate' picture types. This reduces the matrix to the form shown in Figure 6-4.

Now, it has already been pointed out that metaphoricity is a matter of degree. The terms 'realistic' and 'analogical'
seem to correlate with the terms 'literal' and 'non-literal', which, it will be recalled, stand for the extremes of the continuum called 'modes of correspondence'. It follows that I would contend that 'realistic' and 'analogical' cannot be sustained as discrete categories, but should also be regarded as opposing tendencies. A similar situation exists with regard to 'schematized' and 'non-schematized', which are also matters of degree. That is, pictures may be more or less barren of detail. This variable termed **modes of depiction** is dealt with in the next chapter.

So, rather than picture types occupying discrete cells of a matrix, I would argue that a more appropriate scheme, based on Knowlton's terminology, would involve a realistic/analogical continuum plotted against a schematized/non-schematized continuum. This might be represented spatially as in Figure 6-5. This radically reorganised scheme is closer to the proposals of the thesis presented here, some of which have been put forward already.

By discussing, and in part criticizing, the taxonomies of Peirce and Knowlton, I have sought to point out that the distinction they suggest, between the way diagrams and metaphors relate to what they mean, is at best tenuous. I am, in fact, proposing that some diagrams, or perhaps parts of some diagrams, are really a species of pictorial, or graphic metaphor.

This position will be developed through a discussion of the use and value of metaphor in diagrams.
6.3 The value of metaphor in diagrams

In their article entitled 'The diagram is the message', Shera and Rawski (1968 p171) observe that,

'The diagram is a special case of picture making: it bodies forth its subject in a pictorial way, in shapes which themselves possess a characteristic content, but are used to represent another.'

I would assert that when a diagram 'bodies forth' and uses one characteristic to represent another we may legitimately describe this as a metaphoric act. An interesting example of physical properties being transferred metaphorically to an intangible referent is the case of the 13th century diagram representing the Holy Trinity, shown here in Figure 6-6. It is called the 'Trinitas' and one cannot help being reminded of the circle diagrams of syllogistic reasoning dealt with in Chapter 3. The Trinitas tries to show the unity and indivisibility of the Trinity - the three in one. This is something that cannot be pictured literally and it is clear that we are not supposed to believe that the trinity actually looks like the three interconnected hoops depicted in the diagram. However, certain physical properties of the content model are to be thought of as also belonging to the content proper. If one studies the three hoops it will be seen that they are all interlocked, and a physical model could not be taken apart without breaking one of them. What is important is that they are interwoven in such a way that if one is removed, the remaining two cease to be linked. We are to assume that in a similar way the trinity is at the same time both three and one and can never be thought of, for example, as two plus one.

Such early uses of diagrams illustrate one important property they can have which is of great significance, especially in science. This is the potential to represent the non-phenomenal world.

In his chapter on 'models for theory' Arnheim (1970 p280)
suggests that whilst his readers might accept his contention that 'reasoning about the nature of the physical world takes place within perceptual imagery...', they may not be so willing to accept that the same is true for non-physical subjects. However, he points out that the kind of highly abstract pattern he has in mind,

'...is applicable to non-physical configurations as readily as to physical ones, because there again the concern is with patterns of forces, a purpose best served by exactly the same means. In fact the approach is so similar that only by paying explicit attention to the difference in subject matter does one become aware of the ease with which the mind shifts from one to the other.'

This could also be said of diagrams, which some would claim are the graphic representations of reasoning (cf Peirce 4.355, quoted in Chapter 3). As we contemplate the patterns exhibited in diagrams, so we are able to make inferences about the things they represent, things which in many instances can never actually be seen. It is this ability to make the invisible visible, especially via the medium of metaphor, which makes diagrams so powerful, and, incidentally so potentially misleading.

'...when the metaphor is taken for a literal description of what goes on in the universe, imagination is led astray...' (Arnheim 1970 p293).

There are undoubtedly people who believe that atoms are like tiny billiard balls on sticks. This may be because their understanding of such phenomena is derived from diagrams of the sort shown in Figure 6-7. The bonding between atoms is shown here by what may be described as lollipop sticks, although it could be illustrated in many other ways. Some alternatives can be seen in Figure 6-8. The source from which this diagram is taken claims that C 'reveals more about the actual molecular shape'. (Mitchell 1976 p139). An earlier and somewhat more fanciful portrayal of how atoms bond is shown in Figure 6-9. Here, then, we have both the value and the curse of metaphor in diagrams.
Consider Figure 6-10. It shows an alveolus (marked T) or 'refuelling point', of which there are millions in our lungs. The bronchi (marked U) bring oxygen, shown here as truck-loads of bubbles, to the alveoli. Blood vessels marked OOX bring truck-loads of dark, 'used', carbon-dioxide laden blood. The loads are exchanged in the sphere. Carbon-dioxide is carried through U to be breathed out while the blood, reloaded with oxygen, is returned to the heart through OY.

By definition diagrams are static and the expression of movement is therefore problematic. Here the solution is to depict a content model which looks like a subterranean, elevated roadway system, with trucks emerging from and disappearing into tunnels. Whilst there are certain literal correspondences with what is represented, the various significant elements depicted rely heavily on metaphor. In her book on the Graphic representation of models in linguistic theory, Stewart (1976) speaks of 'positive', 'neutral' and 'negative analogy' or, as I would prefer, metaphor [4]. In this case a major, positive element of the metaphor would be the transference of movement to the blood and oxygen, movement being an attribute we normally associate with trucks. Picturing movement is especially difficult when what is moving is the transparent medium of oxygen or the dense medium of blood. Conventionalized indicators such as arrows are often resorted to in such cases. Other attributes, such as carrying, travelling along established routes, being loaded and unloaded, would also be regarded as positive or at least neutral. Negative attributes are that trucks run on fossil fuel and their drivers need H.G.V. licences. Bearing in mind the sophistication of the intended audience of the diagram, this is unlikely to be a problem. The extreme situation of someone actually thinking that little trucks run around our bodies is improbable. A more serious negative attribute might be the fact that there is no contact between the loads of separate trucks, whereas I assume that the blood at least flows in more or less continuous streams. Also, whilst it might be expected that

[4] The term 'analogy' often seems to be used in preference to 'metaphor' where it is assumed that what are irrelevant features of a metaphor have been removed by schematization. This issue is dealt with in more detail in the next chapter.
one will not assume that the bronchi really carry two-lane motorways, is one supposed to assume that alveoli are spherical?

It should be clear from these comments that no guarantees can be made about what readers may infer from such a diagram as this. It should also be clear that correct interpretation relies heavily on the culture of the reader. A person from a society which did not use trucks for the movement of goods, rare though such a society might be today, is unlikely to understand much of what is intended by the diagram maker. There are doubtless many other cultural barriers to understanding in this diagram. In dealing with the same issue, Shera and Rawski (op cit p178) tell us that,

'as soon as we are not attuned to the inferential situation and, if you will, the style of thought which generated the diagram, we find it difficult to read the picture.'

Figure 6-10 requires a considerable amount of pre-knowledge of the subject matter on the part of readers if the distinction between the literal and metaphoric is to be understood. This may be easier in Figure 6-11 than it is in Figure 6-12. In Figure 6-11 the use of metaphor is fairly evident, while I would argue that the mode of correspondence between the content model of Figure 6-12 and what is represented is less easy to discern.

'It is so very easy to conflate the diagram with what it is supposed to represent and accept uncritically as properties of the "real" subject those which, in fact, are emblematic properties of the diagram.' (Shera and Rawski op cit p184)

It is perhaps worth making the observation here that unlike literal diagrams, metaphoric diagrams are, potentially at least, capable of exhibiting the same content with a variety of content models. For example, family relations are often represented by a tree-like content model, whereas it is conceivable that something akin to a Venn diagram
Figure 6.11
From: Sauret A
Le Livre de la Santé
Monte Carlo
could be used (see Figure 6-13). In this case various
generations are represented by different enclosing circles,
and this, perhaps, is closer to the way some people
normally think of family groups. Certainly such
expressions as 'the family circle' are often used in
conversation.

Conversely, Shera and Rawski (op cit p181) observe that
'a variety of situations is mapped with essentially
identical graphic shapes'.

Metaphor, then, is a flexible and extremely valuable
ingredient in diagrams, allowing the representation of what
otherwise could not be pictured. However, the warning of
Shera and Rawski (op cit p184) should be heeded:

'As a medium for communication of thought diagrams
are easy, direct, tangible - we almost said
healthy. These properties, in turn may beget undue
affection for them, and we may diagram what cannot,
hence should not be diagrammed.'

Diagrammatic metaphor must be used with some caution as
meaning must be inferred and it can be never guaranteed
that a reader will see what the diagram maker thought was
implied; more or less than is intended may be construed.
One might say that diagram makers draw diagrams and readers
of diagrams draw inferences.

Of course the more strongly a metaphor is governed by
convention, which in a sense means the more clichéd it is,
the more predictable is the likely interpretation by those
who share the convention. The novel may delight but can
mislead; the well established can be understood but may
bore. The quest for a balance between the innovative and
the informative is the task of the designer of diagrams.

The mediating role played by convention in establishing the
correspondence between the content model and what is
represented will be considered next.
It is a simple matter to state directly in a diagram that B is to the right of A and to the left of C. Both the situation described and the diagram have spatiality in common. Expressing movement from C through to B to A, however, cannot be shown quite so directly. Movement in the diagrammed cannot be shown by movement in the diagram, which by definition is static [5]. Motion must be implied by the diagram maker and inferred by the reader. This may be achieved by picturing a situation with which the reader may be supposed to be familiar, which has movement as a characteristic, so that this attribute may be transferred to what the diagram is to be taken to represent. The metaphor of roadways with trucks is used in Figure 6-10 and one can also think of such things as rivers or canal systems with boats, railway networks with trains, etc.

The best known device for indicating movement in diagrams is the ubiquitous arrow which has metaphoric origins. When fired from a bow, an arrow has both direction and movement. These attributes may be transferred to its static representation - and by association to other things with which it is pictured - in a range of contexts quite alien to archery. 'The arrow' Gombrich (1974 p258) tells us, 'is one of a large group of graphic symbols that occupy the zone between the visual image and the written sign'. It is true that this device has become so conventionalized that knowledge of archery is not essential in order to learn its meaning. By common usage the arrow has been almost transformed from a picture or icon into a symbol. It is of interest to note here that some who deny the usefulness of classifying signs as iconic often point out that such classifications neglect to take account of the fact that signs have histories and are subject to 'deiconization'. I presume an arrow may be taken as such a case. The reverse process, however, that of symbols becoming icons, seems to be less in evidence (cf Sebeok 1978 p120). I take the view that despite the fact that the
Figure 6-14

5 7
6 10

Figure 6-15

From Batteraby A 1966
Mathematics in management
London: Penguin Books
(Fig 2-8)

arrow sign is strongly underpinned by convention, its appropriateness when used as an indicator of movement and direction owes much to its pictorial origins and the characteristics of real arrows.

Now let us consider Figure 6-14, which shows what could be a detail from a critical path diagram such as the one shown in Figure 6-15 [6]. The meaning of this detail might be taken as being entirely governed by convention. Indeed it is undoubtedly a matter of convention that the elements labelled 5, 6, 7 and 10 relate to some planned events in the future. However, the fact that the content model which contains those elements predicts that event 5 will occur before event 7, and 7 before 10, seems to me to have its correspondence with the planned sequence of events rooted in our experience of the real world around us. For example we might take Figure 6-14 to be an aerial view of roads - a map if you will. Suppose 5 and 6 are houses, 10 is a well and 7 a bridge over a stream. Our experience, or at any rate, the way we construe our experience, tells us that if we live in the house at 5 we must pass over the bridge at 7 before reaching the well at 10, while if we live in the house at 6 a more direct route may be taken.

Even if we restrict ourselves to the reality of the page and merely trace our finger along the lines, we find that we pass 7 on our way from 5 to 10.

Consider a further example. We see a flock of sheep in a field. Three of the sheep are separated from the rest of the flock by a pen. The meaning we ascribe to this situation, at the fundamental level of noting three separated from the rest, is the same meaning we ascribe to some diagrammatic display where three elements from a larger group have been encircled by a line.

This is all very obvious and perhaps even appears trivial, but there is an important point to these examples. It is that while diagrams relate to what they mean by the operation of convention, it does not follow that the
organization of the elements within diagrams is arbitrary. This point is made because convention and arbitrariness are often associated and placed in opposition to motivation or iconism (cf Eco 1976 p189). If a configuration is entirely arbitrary and its meaning is established purely by convention, then I would say that what we have ceases to be a diagram. An example which comes close to this will be considered next.

It will be recalled that Peirce's (4.418) definition of diagram is that it should be 'predominantly an icon of relations and is aided to be so by conventions'. An admirable definition, but what may seem curious is that for Peirce (2.279) the term icon embraces an algebraic formula. '...an algebraic formula is an icon, rendered such by the rules of commutation, association and distribution of symbols. It may seem at first glance that it is an arbitrary classification to call an algebraic expression an icon; that it might as well, or better, be regarded as a compound of conventional sign. But it is not so. For a great distinguishing property of the icon is that by the direct observation of it other truths concerning its object can be discovered than those which suffice to determine its construction...This capacity of revealing unexpected truth is precisely that wherein the utility of algebraical formulae consist, so that the iconic character is the prevailing one.'

Macdonald-Ross (1979 p228) voices an objection to this counter-intuitive classification:

'There are serious objections, in my opinion, to any classification which uses psychological factors (such as having new thoughts) as a necessary defining characteristic of an objective part of the external world...'

Having said that diagrams use their spatiality to represent relations, I am obliged to consider formulae as contenders for this category. After all, if one removes the terms of
a formula, one is left with a form or structure which one might well describe as a verb space. Where the terms are placed within the structure will govern their spatial relations with each other, and consequently their meaning. This is also true of written sentences. However, unlike sentences and in common with diagrams, formulae can more fully utilize the two-dimensional space of the page, as when terms are placed over one another. Their verb space is not restricted to the essentially one-dimensional pattern of writing, which is also one-directional.

Consider Figure 6-16 in which q can refer backwards, as it were, when considered against the usual left to right reading convention. That is, we may think of it as saying 'q times the contents of the square brackets' or 'the contents of the square brackets times q'. This formula does not rely on direction for meaning in the same way that the following sentence does:

'John hit Bill.'

Reading this from right to left changes entirely the meaning of the sentence.

I would suggest that there is even a tendency for the Gestalt factor of closure to operate on brackets and parentheses, although the support of convention comes more into play the further apart enclosing pairs are placed. We might perhaps see Figure 6-16 in terms of Figure 6-17, which has the character of a Venn diagram.

It is of course possible to reorganise algebraic formulae so that, using the appropriate conventions, they can be read as single, one-dimensional, one-directional strings of characters, and this is done in computing. However, this is not so very different from converting the content of flow charts, which certainly are diagrams, into the sequential strings of code that comprise computer programs. The potential for reorganisation into a non-diagram is no denial of diagrammatic status [7].

However, when we consider the mode of correspondence, it appears impossible to discern anything we might call.

\[
\left(\frac{x+y}{z}\right) \left(\frac{x-y}{w}\right) q
\]
similarity, or parallelism, even of a metaphoric nature, between a formula and what it represents. There would seem to be an inevitability about the fundamental interpretation of structures such as the one shown in Figure 6-14 which is not shared by algebraic formulae. Formulae rely entirely on convention to establish the meaning given to their spatiality. They make no appeal to our everyday experience of the world. Look at the equation for a circle, which shows the relation of any point P on the circumference to a set of perpendicular coordinate axes:

$$x^2 + y^2 = r^2$$

Now consider Figure 6-18 which shows what the formula is describing. One is bound to conclude that the equation and what it represents are related only by convention. There do not appear to be any obvious properties of the formula which may be transferred to what it means, except by way of the established codes of algebra.

So, in common with other diagrams, algebraic formulae use the organizing potential of two-dimensional space, but relations within that space are heavily governed by convention. The correspondence between the significant elements of formulae and what they are taken to represent seems to be entirely a matter of convention. Some formulae seem to use organizing principles no different from those of writing, eg,

$$x + y = 1$$

whereas others seem to have more the character of diagrams. See for example Figure 6-19. But, by the definition used in this dissertation, algebraic formulae should not be classed as diagrams. Relations in diagrams are used to illustrate relations in other objects. Algebraic equations on the other hand, symbolize relations.

The case does not seem to be quite the same for chemical formulae when presented in the form shown at the bottom left of Figure 6-20. Here certain characteristics of the content model are similar to the trimethyl benzene molecule represented by this formula; namely the verb space linking the terms in the diagram corresponds topologically to the
structure created by the sequence in which the atoms are bonded in the molecule itself. This, then, is unequivocally a diagram. It is of interest to note that the closed-chain or ring theory of the constitution of benzene was proposed by Friedrich August von Kekulé following a dream in which he saw a snake biting its tail [8]. This is shown at the top of Figure 6-20.

[8] Friedrich August von Kekule was professor of chemistry at Ghent and he related to a scientific convention how, one afternoon in 1865, he discovered the idea for the ring theory of the molecular structure of benzene:

'I turned my chair to the fire and dozed. Again the atoms were gambolling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by repeated visions of this kind, could now distinguish large structures, of manifold conformation; long rows, sometimes more closely fitted together; all twining and twisting in snakelike motion. But look! What was that? One of the snakes has seized hold of its own tail and the form whirledockingly before my eyes. As by a flash of lightning, I woke...' (Jones 1969 p31)
Wyld (nd) gives us two meanings for rhetoric; first the traditional sense:

'The art of oratory; theory and practice of elegant and persuasive speaking.'

And second, the more derogatory sense in which the term has come to be used:

'Flowery, showy, high-flown, highly decorated or bombastic style in speaking and writing; style designed to appeal to the emotions more than to reason.'

This latter definition could apply to some diagrams; however, it is the application of the more traditional meaning which will be considered here.

'Rhetoric' and 'metaphor' are sometimes used as synonyms (cf Goodman 1976 pp81 ff), and metaphor is often regarded as a sub-division of rhetoric (cf Nuttall's Dictionary 1951). In any event they are closely associated. In its more general sense rhetoric, like metaphor, has visual counter-parts mainly used in advertising, but not exclusive to it (Garland nd). Of all the types of rhetoric, hyperbole is probably one of the most evident in diagrams.

'Hyperbole...Figure of speech which consists of obvious over- or under-statement, intended to give emphasis and not deceive...' (Wyld op cit)

Certain aspects of rhetoric which involve what may be termed 'within-domain' expansion, contraction, and inversions have been represented diagrammatically (Goodman op cit p82). This is shown in Figure 6-21.

Whilst the effect of visual over- or under-statement is often to give emphasis, in diagrams their use it can also be matter of convenience.

Consider Figure 6-22 which represents the gradient profiles for railways. In terms of how these diagrams correspond to
Figure 6-21
From: Goodman (1976 p92)

"Large"

"Small"

a. Literal application  c. Understatement  e. Underemphasis
b. Hyperbole         d. Overemphasis
                    (under/overstatement)
f. Irony

Figure 6-22
Gradient diagrams by Somerset and Dorset Railway

Figure 6-23
From: Brown R. and Science for all Vol 4
London: Cassell, Petter & Gullin & Co p212
the actual stretches of track, we may regard the horizontal
distances in the content models as being compressed, or we
may think of the altitudes as being extended. The
resulting exaggeration of gradients serves both to make
them visible and exhibitable in a compact diagram. If
these profiles were drawn to scale, the variations in slope
would hardly be discernible. A similar technique is used
in Figure 6-23 in order to show the altitude of the Thames
at various points along its course.

Another useful rhetorical device is that of synecdoche,
which is defined as a,

'figure of speech in which a part is used to imply a
whole; eg blade for sword; sail, keel, bottom, for
ship; hand for workmen.' (Wyld op cit)

If we take each man in Figure 6-24 to represent the whole
population of which he is part, then here we have something
close to what we might well term diagrammatic synecdoche.
A more rational use of this technique is proposed by
Neurath (1936), where instead of one man representing the
whole of some population, each graphic device represents a
fixed number. Different proportions are thus shown by
varying the number of units depicted in the content model,
rather than by variations in their size. This technique is
used in Figure 6-25 to show an increase in the number of
cars from 1920 to 1932. It depicts a content model which
we may take to correspond to a proportionally
representative part of the world population of automobiles
at three separate times during the period in question.

Figure 6-26 shows an interesting use of diagrammatic
synecdoche which also involves a graphic equivalent of
metonymy, that is a,

'Figure of speech which consists in putting the name
of one thing for another, the substituted word
expressing an object or idea closely associated with
that for which it stands; eg fond of the bottle for
fond of drink, wine, etc.; fur and feather for
beasts and birds etc. (Wyld op cit)
The heights of these figures are in proportion to the population of the United Kingdom at each of the censuses which have been taken.
In Figure 6-26 a single vine is used synecdochically to represent all the vines of a particular continent, thus metonymically standing for its wine industry. Each bunch of grapes is a metonym for the wine output of individual countries.

Alliteration is another characteristic of speech often associated with rhetoric, although it is essentially syntactic in nature (cf Goodman op cit p81). Alliteration is the,

'Recurrence of the same consonantal sound in stressed syllables of several words in a series, in prose or verse.' (Wyld op cit)

In Figure 6-27 the hunched position of the jockey is stressed by the visual echo of his profile in the enclosing outline. This is perhaps a contender for the category of visual alliteration.

It would seem, then, that rhetoric and associated modes of speech can in some cases have a visual counterpart, and an exhaustive series of examples is unnecessary to demonstrate this. The point is that the mode of correspondence between a content model and what is represented can be subject to mediation by a process we might well describe as diagrammatic rhetoric.
6.6 Mnemonic diagrams

One useful function of diagrams is to act as visual mnemonics. If we can remember the pattern of the diagram we are halfway to remembering its constituents, and this process seems to be aided to the extent that symmetry is involved in the visual structure. I would observe, incidentally, that what one might term the 'symmetrical imperative' often seems to have been in operation in the design of many diagrams.

In some diagrams the relational meaning seems weak and a primary function of their form appears to be to act as a vehicle for the naming of the parts. The content model, if you will, provides a set of hooks on which to hang labels. See for example Figure 6-28, which is not really a diagram at all unless we are to assume that logic rests on epistemology and metaphysics in some sense or, say, that ethics and aesthetics have some equivalence. However I do not think this is meant to be the case. Here there is no literal, metaphorical, or conventional mode of correspondence between the content model and anything, as nothing is represented.

In connection with mnemonic diagrams it is perhaps worth mentioning the 'Number-Forms' described by Galton (1907 pp79-105). One of Galton's (op cit p96) correspondents described them as "the apparent positions of numbers in my mind". These images, some of which are shown in Figure 6-29, may have been an aid to counting at some stage in their owners' development. Of note is example 37, where the positions of the numbers one to 12 are assumed to be "due to learning the clock" (ibid).
Figure 6-29
From: Galton (1907 p97)
Summary

The use of metaphor in language was outlined and the terms 'tenor', 'vehicle', and 'ground' were introduced. The concepts of 'within-domain' and 'between-domain' distance were also discussed.

The case for extending the use of certain terminology, usually associated with language, by applying it to diagrams has been presented.

The value of graphic metaphor, especially when used in scientific diagrams, has been pointed out. Also some of the potential hazards of misinterpretation have been alluded to.

It was pointed out that, unlike literal diagrams, non-literal diagrams are potentially capable of exhibiting their contents with a variety of content models.

The case for algebraic formulae being diagrammatic was considered and rejected. The role of convention in diagrams was discussed.

The concept of a diagrammatic equivalent of rhetoric has been proposed and the mnemonic use of diagrams has been suggested.
Chapter 7 MODE OF DIAGRAMMATIC DEPICTION

7.1 Abstraction in diagrams

7.2 Schematization in diagrams

7.3 Modes of depiction

Summary
'Abstract' is an adjective frequently applied to certain sorts of picture. When it is used in the sense of simplification or reduction, it is often thought to be a defining quality of diagrams (cf Shera and Rawski op cit p172, Arnheim 1974 p147). There are objections to the first usage, and I reject the notion of reduction as a necessary distinguishing feature of diagrams.

These issues will be dealt with separately. First we will consider the meaning of the term 'abstract' in general [1]. Something which is abstract is defined by Wyld (nd) as,

'Existing, or thought of as existing, apart from material objects, opposed to concrete; hence, ideal, not practical.'

For example hardness, considered separately from an actual hard object, is an abstract idea. Abstraction then leads to general concepts which are used to group particular instances. Hence such concepts as man, animal or roundness are all abstract.

As a noun it means,

'Something taken out, summary, epitome' (Wyld ibid)

So in this sense it seems reasonable when Albarn and Smith (1977 p61) tell us that,

'Most drawn or painted images are, whatever their content or medium essentially abstract.'

No painting, however realistically it portrays its subject matter, can have all the qualities of the things represented in it. Certain aspects must be abstracted; or, as it were, extracted from the scene in the mind of the artist in order that they may be depicted in the picture.

However, Guiraud (1975) tells us that 'to speak of "abstract painting" is erroneous because all painting is concrete', and as for "non-figurative painting", it is 'an icon of non-figurative...reality'.

[1] An interesting discussion by Arnheim (1970) on this is contained in his chapters entitled 'What abstraction is not' and 'What abstraction is'.
This also seems reasonable, as a painting certainly is a concrete object. If its subject is its own reality and it does not, as it were, reach beyond itself to portray something else, then to speak of abstraction is, strictly speaking, inappropriate.

Taken together, the pronouncements of Albarn and Smith (op cit) and Guiraud (op cit) turn on its head the usual distinction made between abstract art and what is sometimes called representational art. Art forms are usually described as abstract when they are concerned with the aesthetic values of form and colour independently of any subject matter, while representational art is very much concerned with its subject (cf Murray 1976, Mills 1965).

Because of these and other problems, the use of the term abstract will be avoided when dealing with diagrams. I will give an illustration of the sort of difficulty which can arise.

It will be seen that the content of a diagram itself may be abstract, in the way an elaborate botanical diagram may represent all members of the species depicted (see Figure 7-1). On the other hand the content of a diagram may be particular, in the way a very simplified depiction may represent a single unique piece of circuitry (see Figure 7-2). However, in everyday speech the wiring diagram may be referred to as abstract whilst the botanical diagram may not. What we may conclude, when the term is used in this way, is that abstract is not being applied to the ontological status of the content, but rather to the extent to which the actual image is barren of detail. This is an important variable available to the diagram maker, and in order to deal with it we need a convenient and appropriate terminology.
Gombrich (1977 p247) tells us that,

'...all representations can be arranged along a scale which extends from schematic to impressionistic.'

This seems to correspond to the 'scales of iconicity' proposed by Moles (1968 pp24-26), and at first glance, it might suggest a one-dimensional continuum. If this were the case the continuum might range from the highly coloured and shaded images we expect to see in colour photographs, through monochrome tonal scenes, to what might be termed the impoverished depictions of minimal black-on-white outline drawings. It should be noted here of course that such impoverishment does not necessarily mean that the depiction will be of lesser value as a means of imparting information. Albarn and Smith (op cit p61) observe that.

'A black line-drawing on a white field is the clearest form of visual communication, indeed it could be argued that it is the clearest form of communication.'

An example of 'less is more', to echo Mies van der Rohe (Blake 1963).

As it is outlined above, one could think of this image impoverishment as akin to tuning out the colour in one's television set, or adjusting the contrast on a monochrome set to produce an effect like the one shown in Figure 7-3. Taking this illustration further, we may suppose we have a special computerized video monitor with some additional image control knobs which allow the user to tune the tone in and out as opposed to merely altering the contrast. This would allow the production of colour images without tonal modelling. One knob might control changes in the range of colours while another might produce outline effects. The different sorts of images which may be produced by the interplay of such controls could not be arranged in a single logical sequence, each representing a different level of impoverishment. A better notional scheme might be to envisage such variables as directions...
within a plane, with the effect of each knob of our special image modifying device being represented by a separate direction.

It should be noted that all the types of image modification referred to so far do not involve variations in projection. Metric values are unchanged. Here we are dealing with an aspect of what an illustrator might call rendering. Another aspect of rendering, closely related to what I have been describing, is called 'gamut' by Ashwin (1979 p59). He tells us that an illustrator, '...may, for example, limit the direction or length of lines to a certain range of selected possibilities; or he may reiterate the form and scale of certain favoured shapes; or, if working in colour, he may limit the range of hues or combinations of hue. The breadth of effects employed within the chosen medium may be described as the image's gamut.'

All these variables contribute to what generally we might term style, and style can have a great effect on the mood of an illustration, without necessarily influencing the internal relational content.

There are, however, organizational possibilities which tend to emphasize relational aspects in diagrams differentially, and these are more synoptic in character than the kind of image impoverishment outlined above. For example, in Figure 7-2 the topology is emphasized more than other relations, while Figure 7-4 tends to stress the relative size at the expense of other features. These effects are not produced by simply turning out the colour, or rendering in outline only, but require another sort of simplification; a reorganization which, as it were, epitomizes relational characteristics. The term, schematization will be used here to denote this synoptic process [2]. It will be used in preference to abstraction which, as I have already suggested, can sometimes confuse the nature of the depiction with its content, and this is an important distinction to maintain.
Now a 'schema' is an 'appearance, form...an outline, figure, synopsis' (Wyld op cit), and it follows that 'schematic' means 'of the nature of a scheme, or a schema; arranged in a diagrammatic or synoptic form' (ibid).

Schematization, then, clearly refers to the mode of portrayal rather than the content, and it implies a synoptic character which is just the meaning required here. Schematization, in emphasizing relational characteristics, is of special importance for diagrams and it also may be thought of as occupying a notional plane where different directions represent different modes of this synoptic reduction.

Figure 7-5 shows this directional notion of schematization.
7.3 Modes of depiction

In this dissertation the manner in which a content model is portrayed, that is the degree of schematization involved in its production, will be termed the **mode of depiction**.

This variable is concerned with the way objects are depicted in diagrams and hence is related to the way diagrams are interpreted at the semantic level. The modes of depiction range from the **figurative** through the **semi-figurative** to the **non-figurative**.

A non-figurative mode of depiction represents the extreme of schematization where only the most generalizable qualities are suggested. For example, consider in Figure 7-6. The leader lines which link parts of the anatomy to their labels are non-figurative in their mode of depiction. They do not compel us to regard them in terms of, say, chains, ropes, or any other objects which have a lineal character. Because they are highly schematized it is the linearity of the leader lines which is emphasized. It is as if the reality they portray is restricted to the reality of the page. Here we infer the abstract notion of connectivity; other more figurative graphic devices could suggest this, but they would have other attendant attributes that might be more or less appropriate.

On the other hand, the depiction of branches connecting related musical works in Figure 7-7 tends towards the figurative and the tree metaphor is quite evident. This has a decorative function, but also invites us to transfer certain additional characteristics of trees to what is primarily represented. That is, as well as the associations implied by the sequence of labels and the sharing of branches, the idea of growth may be inferred by the reader.
Figure 7-7
From the record sleeve of Andrew Lloyd Webber's "Variations"
The tree-like character is less intrusive in Figure 7-8 where the branches are schematized. The metaphor has been to some extent neutralized and we have what Stewart (1976 p137) might call an 'armature diagram'. However, the plant-related possibilities for meaning remain and this is perhaps a candidate for the semi-figurative territory.

It might be argued that the notion of a metaphoric correspondence is, perhaps, less appropriate than an analogic one when the mode of depiction is essentially schematic. 'Analogic' might appeal as it has a more scientific ring and is somehow less mystical than 'metaphoric'. Note for instance a comment of Stewart's (op cit p22) when discussing some of the problems of using tree-like models in linguistics:

'...it furnishes the diagram with a metaphor which at times usurps the place of the analogue.'

I would argue that the sense in which 'analogue' is used in this quotation is no different from the sense in which 'metaphor' is used throughout this dissertation. I would argue that neutralizing the negative aspects of a graphic metaphor by means of schematization does not change its status as a metaphor. Anyway, to be strict, the term 'analogue' refers to a system of proportions. This limits its legitimate application and would certainly exclude correspondences with tree-like structures. If the term 'analogy' is used in a sense other than in reference to a system of proportions, it would seem that it is being used metaphorically!

Another issue arising from ideas surrounding the mode of depiction is the notion of some form of abstraction or schematization being the defining characteristic of diagrams. This is an idea which, as I have already indicated, is rejected in this dissertation.

Consider for example the human blood circulatory system. A detailed picture of the heart with some arteries and veins could be made which closely resembled the real organ. See Figure 7-9. We should be able to identify from the drawing...
the corresponding parts in an actual specimen, but I suggest we would not ordinarily call such a picture a diagram, especially if it was hanging in an art gallery. If, however, we added some arrows showing the blood flow direction and a labelling scheme which differentiated arteries from veins, could this not then function as a flow diagram? This additional information could be added to the original picture by a lecturer using the spoken word and gestures with a pointing finger. In this case the diagrammatic status would be only transitory.

This picture could of course be less realistic - more schematized - and perhaps we could still identify what the various parts represented from their general shapes and position. Maybe the heart would look vaguely like the heart emblem from a pack of playing cards (see Figure 7-10).

At a further level of schematization, the heart could be shown by a set of interconnected rectangles and the blood vessels could be represented by lines of standard width. These would indicate the essential topology of the system (see Figure 7-11). The veinous and arterial classification could be shown by different colours. The general appearance and function of such a graphic display would have more in common with a plumber's diagram than would the original picture, but an element of resemblance would remain.

If at this stage we removed all arrows and labels we probably would not recognise what was represented - the display would cease to function as a diagram and might look more at home back in our art gallery. So it is not necessarily the degree of schematization in a picture which makes it a diagram, and clearly the content models in some diagrams look more like the objects they depict than others. The deciding factor is one of function.

If the purpose of a pictorial display is to exhibit relational information by means of its graphic structure, then I would argue that the display should be regarded as a diagram.
The unsatisfactory nature of the term 'abstraction' when applied to diagrams has been pointed out. In preference the term schematization is used to denote the process of image reduction which leads to what may be thought of as a synopsis of relations. Schematization can be thought of as having a directional character.

The extent to which a diagram is schematized is called the mode of depiction, which may range from the figurative through the semi-figurative to the non-figurative.

A further justification is given for the notion of a metaphorical correspondence in diagrams rather than an analogic one, even when the mode of depiction is schematized. Analogic refers to a system of proportions and is therefore more restrictive in its use.

The idea of some form of abstraction or schematization being the qualifying characteristic of a diagram is rejected in favour of a definition which includes their use in exhibiting relational information.
8.1 Modes of interpretation
8.2 Modes of organization
8.3 Grouping in diagrams
8.4 Linking in diagrams
8.5 Variation in diagrams
8.6 Mixed modes of organization

Summary
8.1 Modes of interpretation

Diagrams have been partially defined as graphic displays which are used to exhibit relational information through the interaction of the significant elements in the content model. Significant elements can be thought of as occupying either subject or predicate spaces and may have a more or less literal correspondence with what they represent. They may also be depicted more or less figuratively. The mode of correspondence and mode of depiction have been identified in this study as two important variables available to the designer of a diagram. They are important as they may be supposed to have a greater influence on the meaning attached to a diagram as a representation of relations than other variables such as, say, style of rendering (insofar as this can be distinguished from the mode of depiction). The modes of correspondence and depiction relate to the semiotical levels of pragmatics and semantics, which, together with the syntactic level, govern the interpretation readers place on diagrams.

A characteristic of both the mode of correspondence and the mode of depiction is that each can be regarded as a continuum, with various significant elements of diagrams being placed nearer or further from the territories of the literal and the figurative. This suggests a classificatory space which is two-dimensional, with the modes of correspondence plotted against the modes of depiction. Such an arrangement might appear as in Figure 8-1. Of course the various boundaries in this diagram should not be thought of as definite, but rather each territory should be regarded as merging into the next. This could be represented by colours shading into each other.

However, it has already been pointed out that the process of schematization associated with the mode of depiction is not strictly one-dimensional in character; it is more appropriately thought of as having different directions, as suggested in Section 7.2 in the last chapter, and shown in Figure 7-5.
To accommodate this idea the content model shown in Figure 8-1 is changed to a cylinder, where the upward direction represents a movement away from the non-literal and an outward movement towards the circumference represents a movement towards the non-figurative. For ease of depiction this will be shown as three disks, each standing for a stage on the mode of correspondence continuum. The concentric rings on each disk represent the modes of depiction. This is shown in Figure 8-2. Again the separate planes and the boundaries should not be thought of as definite; rather each area should be thought of as merging into the next.

It has to be admitted that it might be useful when devising such models to have the option of using a space with one or two more dimensions. Whilst this may be possible for the mathematician, it is not possible for the diagrammatician who literally has only two dimensions. These can be extended, however, by picturing a three-dimensional content model. Although I have already spoken of the apparent possibility of more than one space being pictured in a single diagram, it is only apparent. Although the content model may represent various spaces, it can only make sense when we try to interpret it in terms of two or three-dimensions, even if, when so interpreted, there appear to be spatial inconsistencies [1].

If we had an extra dimension in our model we could perhaps allow for the fact that the mode of correspondence is also not restricted to a single direction. There must be, at least potentially, any number of metaphoric possibilities for representing any particular phenomenon. It will be argued that the more schematized or more non-figurative the significant elements in a diagram become, the more restricted are the characteristics of depiction; however, in the figurative mode the scope becomes unlimited the further one moves from the literal. It is perhaps the case that any classification of the metaphoric possibilities of figurative diagrams would require several extra planes or even spaces. So when regarding the revised model we must
imagine that although the mode of correspondence is
depicted as a single vertical direction, it in fact
represents all possible movements away from the non-literal.

This spatial model will be developed in the next section to
accommodate the mode of organization.

The modes of correspondence, depiction, and organization
may be known collectively as the

Modes of interpretation.

The model, when fully developed, will show how the various
modes of interpretation relate to one another.
8.2 Modes of organization

In Chapter 3 I discussed how a diagram can be analysed into its significant elements and classes of significant elements.

Once this is done, each element or class of element can then be considered against the diagram as a whole in order to discern its mode of correspondence and mode of depiction. When considering the mode of depiction it will be recalled that there is a directional component to the movement away from the figurative. This corresponds to the idea that any graphic synopsis created by schematization will emphasize particular relational characteristics by means of what may be described as the graphical organization of the significant elements. These various organizational possibilities I will term the modes of organization.

During the analysis of the sample diagrams gathered for this study, the following finding concerning these relational characteristics has emerged. The significant elements of diagrams tending towards the non-figurative and non-literal have modes of organization which are limited to combinations of three main types which I call grouping, linking and variation.

They are exemplified in Figures 8-3, 8-4, and 8-5. In Figure 8-3 grouping is exhibited by enclosure; in Figure 8-4 linking is exhibited by connection; and in Figure 8-5 variation is exhibited by size. This graphical organization is to be thought of as primarily a property of the content model, as distinct from what it is the diagram may be taken to mean. With regard to this distinction Stewart (1976 p13) declares that,

'Dangerous as it is to divorce form from content, we must do so in the case of graphic representation in linguistics.'
We must do the same for diagrams in the more general context considered here. I separate form from content in my analysis, but this can be done only up to a point.

In Chapter 3 I indicated an acceptance of certain gestalt principles. In particular, whilst I accept that perception can be to some extent modified by previous experience, there are nevertheless certain ways in which visual phenomena seem to organize themselves, independently of what we recognise them to be or take them to mean. In the case of Figures 8-3, 8-4, and 8-5, I would argue that whilst these diagrams have the potential to refer to an infinite number of states of affairs, what they could be taken to say about those states of affairs is strongly governed by the organization of their elements. These meanings would be those which at the most fundamental level correspond to notions of grouping, linking and variation. It seems that at this level meaning and form are inseparable. The manner in which we construe the forms we see determines the way in which we describe them. The way in which we describe them is their meaning. Some of the diagrammatic possibilities for the modes of organization are given in the table shown in Figure 8-6.

It will be seen from Figure 8-7 that these organizational modes may be exhibited by various graphical means. The row headings

- form
- orientation
- colour
- texture
- tone
- size

are derived from Bertin (1973 p42). To these I have added the possibilities of

- enclosure
- proximity
- alignment
- connectivity

which one might think of as being species of grouping and linking.
<table>
<thead>
<tr>
<th>Mode of Graphic Organization</th>
<th>Usual Diagrammatic Interpretation</th>
<th>Some Characteristic Application</th>
<th>Examples of Typifying Diagrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grouping</td>
<td>Association</td>
<td>Classification</td>
<td>Venn</td>
</tr>
<tr>
<td>Linking</td>
<td>Sequence</td>
<td>Process</td>
<td>Flow chart</td>
</tr>
<tr>
<td>Variation</td>
<td>Value</td>
<td>Ranking</td>
<td>Bar chart</td>
</tr>
</tbody>
</table>

**Figure 8-6**

<table>
<thead>
<tr>
<th>Graphic organization (Diagrammatic interpretation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity (Association)</td>
</tr>
<tr>
<td>Orientation</td>
</tr>
<tr>
<td>Colour</td>
</tr>
<tr>
<td>Tone</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td>Enclosure</td>
</tr>
<tr>
<td>Proximity</td>
</tr>
<tr>
<td>Alignment</td>
</tr>
<tr>
<td>Connectivity</td>
</tr>
</tbody>
</table>

**Figure 8-7**
It will be noticed that some cells in the matrix are empty. These are where the row headings contradict or exclude the column headings.

As with the other modes of interpretation, the modes of organization represent tendencies and are not necessarily discrete categories. They can be present in strong, weak, or hybrid forms. This can be seen in the sequence of diagrams shown in Figure 8-8. All these diagrams exhibit grouping, linking, and variation with differing emphasis. As three modes have been identified, they may be thought of as three directions separated by 120°, with the directions in between representing hybrid modes. This is incorporated into Figure 7-5 shown again here as Figure 8-9.

The nomination of these organizational modes as inevitable consequences of the extremes of schematization in diagrams represents the major outcome of this study.

We will now look at some specimens where each of the modes of organization is strongly in evidence.
8.3 Grouping in diagrams

Figure 8-10 is based on Mendeleev's original periodic table of 1871 (Bronowski 1973 pp321 ff). Apparently Mendeleev wrote out on cards the elements which were known at the time and laid them out in the order of their atomic weights. He found that if he arranged them in columns of seven, the horizontal rows formed groups of elements sharing family likenesses, thus establishing that the sequence of atomic weights was systematic. By considering the sequential relation of weights and the positions of elements within the rows, Mendeleev was able to accurately predict the existence of unknown elements, and their characteristics, from gaps in the table.

So here we have a diagram which makes use of grouping by alignment. In this case the horizontal alignment is of great significance. The verb space uniting the elements is of course non-literal. It does not, for instance, map the distribution of elements as found in the world.

The sequence of weights runs down each column and then from the bottom of the column to the top of the next column on the right, and so on. A more convenient arrangement for displaying the currently known ninety-two elements is shown in Figure 8-11. Here the families of elements are shown grouped by sectors into which the new content model is divided. It has already been pointed out in Chapter 6 that diagrams with a non-literal mode of correspondence seem to have the potential for displaying their contents with alternative models, and this is a good example. Also, each element in the new diagram is linked to the next in an unbroken sequence of atomic weights. This increase in weights is matched by the variation in the distance of the elements from the centre, this distance increasing as the model spirals outwards.

This diagram is taken from a text book for chemists and it is interesting to compare it with a similar diagram
Figure 8-10
From: Bronowski (1973 p324)

\[ \text{H}_7 \text{ L}_7 \text{ N}_8 \text{ K}_9 \]

\[ \text{B}_2 \text{ Mg}_3 \text{ Ca}_4 \]

\[ \text{Be}_{5} \text{ Al}_{6} \text{ Ti}_{7} \]

\[ \text{C}_{8} \text{ Si}_{9} \text{ Fe}_{10} \]

\[ \text{N}_{11} \text{ P}_{12} \text{ Zn}_{13} \]

\[ \text{O}_{14} \text{ S}_{15} \text{ Br}_{16} \]

\[ \text{F}_{17} \text{ Cl}_{18} \text{ Br}_{20} \]
designed to have a wider appeal. Figure 8-12 appeared in the science exhibition at the Festival of Britain in 1951.

A well known type of graphic display which also uses the grouping mode is the Venn diagram, introduced in Chapter 3 in relation to the 'existential graphs' of Peirce (4.347 ff). Next I seek to point out that the enclosing circles of Venn diagrams have a fundamentally similar organizing function to that found in tables. This can be appreciated by considering Figure 8-13. Here grouping by enclosure and alignment are mutually supportive.

Consider Figure 8-14. Because we understand the conventions of graphing, I suggest that when co-ordinate lines are not present, we project them into the chart. We might imagine them as they appear in Figure 8-15. Thus any data points we place in the charts are grouped into columns and rows. See Figure 8-16. Additionally there may be grouping caused by the bunching of points. This effect illustrates the well known gestalt principle of association by proximity which is used frequently in diagrams, especially for grouping labels with the things to which they refer.

The tendency for like to band with like is another well known gestalt principle. Similarity, as a means of establishing groups which should be associated together, and, conversely, dissimilarity, as a means of indicating disassociations, are extremely valuable in the design of diagrams. In fact, sameness and difference are crucial. All diagrams depend to some extent on this species of the grouping mode of organization.

Data points in graphs can be grouped together by linking lines. This might seem to combine two separate categories into a single one. It is true that linking necessarily forms groups among the linked items, but what is particular about linking is the implication of sequence. Certainly, in addition to grouping, the linking lines imply a sequence in the data points of Figure 8-17. This further
illustrates the point that the modes of organization should not be thought of as discrete categories.

In addition, it will be observed in Figure 8-17 that the notion of sequence in the co-ordinate markers is reinforced both by alignment and by the linking function of the axes; also, variation in the distances of data points from the axes is taken as significant. Both of these modes of organization will be considered later.

Although we do not know what is referred to in the examples of grouping diagrams given so far, it may be assumed that their content models have a non-literal mode of correspondence with what they represent.

The grouping mode of organization is also found where there is a semi-literal mode of correspondence. For example, there are maps where contour lines not only group common altitudes together by connectivity, but also group by enclosure territory above or below certain altitudes. In this last sense, contour lines function somewhat like the circles of Venn diagrams. Each enclosing contour includes all the altitudes of the previous contours. However, unlike the application of this idea to the non-literal world of syllogisms, intersecting contours are rare.

Another example involving the semi-literal mode is the case of colour coding used to group associated territories. For example, a map of the United Kingdom might show the areas of the country controlled by Labour councils as red. There would be a literal spatial correspondence to the territories referred to, both for the subject and predicate spaces. The subject space would contain simply a partially schematized outline which depicted the coastline semi-figuratively [2]. The predicate space would be non-figurative, being either red or not red. Difference of colour is transferred metaphorically to mean political difference. Meaning is also assisted by convention, which states that red is the colour associated with the Labour Party. The distribution map shown in Figure 8-18 functions.
in a similar way. The thermogram shown in Figure 8-19 maps various temperature levels with colour coding. Differences in colour stand for differences in temperature and again we are assisted by convention. This time red means hot and blue means cold.

Some further specimens of diagrams exhibiting the grouping mode of organization follow.

Figures 8-20 and 8-21 have content models which are non-literal and non-figurative. (This excludes the statue of Justice which acts as an extra marker for 'Law'. It does not add to the relational meaning and is essentially decorative.)

In Figures 8-22 and 8-23 the subject spaces, containing respectively the violent man and the map of the world, are semi-literal although they are schematized to varying degrees. In both cases the predicate spaces, defining the various zones, are semi-literal in that they refer to actual spaces, but in reality a certain amount of contrivance would be required in order to make them visible.

Diagrams with a non-literal content model are sometimes highly figurative. Figure 8-24 is supposed to illustrate the idea that children learn to behave in a socially acceptable manner because, if they do not, society exacts penalties. Whilst the child confines his topiary to within the outer perimeter of his enclosing hedge all is well, but when he cuts through it the ground falls away. Underlying the figurative depiction is an armature diagram which, in essence, is a kind of Venn diagram. Socially acceptable behaviour lies within an enclosing circle, while outside is forbidden territory and the sanctions of society.

Next, the linking mode of organization will be considered.
8.4 Linking in diagram

The links between companies shown in Figure 8-25 have a non-literal mode of correspondence with what it is they represent, namely ownership. The various connections display quite extensive sequences of investment. For example, Harcros has an 8.7% interest in Killinghall, which has an 0.02% interest in HME. HME has a 4.3% interest in Castlefield, which, to close the loop, has a 0.5% interest in Harcros. Diagramming a complex network of investments like this is extremely problematic if one aims to make all the interrelations clear to the reader. One suspects that in this case the diagram designer is also saying, 'this situation is as complex as one of the complicated wiring diagrams!'.

One of those complicated wiring diagrams is shown in Figure 8-26. It is an example of the linking mode of organization, depicting a content model which has a semi-literal mode of correspondence with what it represents. Essentially only the topology of the wires, which are shown non-figuratively, is preserved in the content model. The convention of using only straight lines which run either vertically or horizontally has been imposed. This is usual for diagrams of this type.

The London Underground diagram of Henry Beck (Garland 1969) is another example where the linking mode of organization is strongly in evidence. It is used here to portray sequential information with much greater clarity than in the examples given above.

An interesting 17th century example of diagrammatic linking can be seen in the numerous figures used by Blome (1686) to display the breakdown of the various subjects he deals with in his Gentlemans recreation (see Figure 8-27). Some have the character of what we might call today a 'language algorithm'.

8/15
Who owns what in whom?

Example: Harrisons & Crosfield has a 21.4% share in Castlefield. The same line shows that Castlefield has a 0.02% stake in Harrisons & Crosfield.
Armstrong Siddeley 18 H.P. 2.3 Litre
"Lancaster" Saloon & "Hurricane" Coupe Cars
Home and Export Models

Lucas Electrical Equipment

Figure 8-26
From: Armstrong Siddeley
Motors 1950
Service Manual

Wiring Diagram
No. W78081
12 Volt

Key to Cable Colours

<table>
<thead>
<tr>
<th>No.</th>
<th>Colour</th>
<th>Colour</th>
<th>Colour</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blue</td>
<td>Red</td>
<td>Brown</td>
<td>Black</td>
</tr>
<tr>
<td>2</td>
<td>Blue with Red</td>
<td>Yellow with Blue</td>
<td>Black with Red</td>
<td>Yellow with Black</td>
</tr>
<tr>
<td>3</td>
<td>Blue with Yellow</td>
<td>Black with Yellow</td>
<td>Red with Blue</td>
<td>Black with Yellow</td>
</tr>
<tr>
<td>4</td>
<td>Blue with White</td>
<td>Yellow with White</td>
<td>Red with Yellow</td>
<td>Black with Yellow</td>
</tr>
</tbody>
</table>

Issued: October 1950

Numbers indicate cable identification colours, see key above.
Some further examples of diagrams using linking are given in Figures 8-28 to 8-35.

In Figures 8-28 and 8-29, gas processing plants are shown with differing levels of schematization. Both are to some extent literal, as is Figure 8-30 which shows how the various organs of the digestive system are linked.

The composite diagram in Figure 8-31 shows which hormone-secreting glands affect which organs. This linking is semi-literal in that the hormones do literally pass from the glands to the organs; however, they make their way through the blood stream by rather less direct routes than the ones shown. The mode of depiction of the connecting routes is non-figurative.

Figures 8-32 and 8-35 have content models which are non-literal. Figure 8-32 uses the conventions of the black and white versions of the London Underground diagram. This perhaps brings to the diagram, by a rather indirect route, the notion of movement around the circuits. These circuits in fact represent the processing of a computer program.

Grouping by similarity is of course in operation in all these diagrams and enables us to determine which significant elements are to be regarded as fulfilling similar functions. For example, in Figure 8-25, similarity indicates which elements represent companies and which investment routes, and, in Figure 8-26, which represent terminals and which wires.

Variation, on the other hand, is less in evidence, but operates to some extent in Figure 8-25. One assumes that the increase in size and the deepening shade of the boxes corresponds to an increase in the importance of the companies represented.

The use of the variation mode of organization will be looked at now.
Most of our food is composed of carbohydrates (blue), the yellow and protein (red), fats (blue) or vitamins all.

The food mixed with saliva from the salivary glands (1) passes to the stomach (2) where gastric juices from the gastric glands (3 and 4) break it down. Then mixing (5) helps the gastric juice to digest the food.

Bill (6) is added, and stomach juices from the pancreas (7), which is rich in enzymes A, B, C, D and E, more enzymes are produced in the walls of the stomach (8).

The enzymes mix with food into very small particles that can be absorbed and transmitted to the general circulation (9) to the liver (10), where the particles are converted into substances the body can use, and are passed through the hepatic vein to the heart (11 and 12), and distributed to the cells of the body by the liver through the bloodstream by the hepatic duct (13).
The pituitary (1) is the leader of the endocrine 'orchestra', that marvelously synchronized assembly of internal secreting glands. Stroked by the neural equivalent of a baton, the pituitary dispatches the chemical messengers, known as hormones, into the blood. This composite diagram of its influence on a woman's sexual function shows only a fraction of its work (the frontal lobe alone largely controls growth and maintenance of the thyroid and the adrenal glands). At puberty the pituitary releases the follicle-stimulating hormone (FSH) and the luteinizing hormone (LH), which act on structure in the testes of boys and the ovaries of girls to bring about sexual maturity. In women of childbearing age the pituitary releases its hormones in cycles every month (unless she is taking the Pill). They act on the ovary follicles to cause one of them to ovulate each month. (see diagram opposite).

At puberty the pituitary releases the follicle-stimulating hormone (FSH) and the luteinizing hormone (LH), which act on structure in the testes of boys and the ovaries of girls to bring about sexual maturity. In women of childbearing age the pituitary releases its hormones in cycles every month (unless she is taking the Pill). They act on the ovary follicles to cause one of them to ovulate each month. (see diagram opposite).

A ripening follicle (2) itself becomes a minute endocrine gland, which secretes hormones called estrogens. It thickens the lining of the uterus for possible pregnancy, makes the vaginal walls more elastic and softens the plug of mucus in the cervix.

Once a follicle has ovulated, a third messenger from the pituitary, the luteinizing hormone (LTH), converts it into another temporary endocrine gland called the corpus luteum (3). This produces, in addition to estrogen, the specialized pregnancy hormone, progesterone, which prepares breasts and reproductive tract for possible pregnancy.

LTH, otherwise known as prolactin, also initiates and maintains the milk supply after childbirth.

LTH, otherwise known as prolactin, also initiates and maintains the milk supply after childbirth.

At term, nourishing of the corpus luteum (4) is taken over by a hormone elaborated by the tissues (5) round the implanted ovum. These tissues, which develop into the placenta (6), secrete upon production of chorionic and progesterone for the ensuing pregnancy. The relatively large volume of these two ovarian hormones prevent the pituitary from scaling out the FSH and LH needed for ovulation.

The Pill contains an ovarest and a compound that acts like a progestin. Its chief effect is to inhibit ovulation by mimicking the hormonal circuit of pregnancy.
Figure 8-32
From: Richards (1980 p19)

FLOW IS TOP TO BOTTOM & CLOCKWISE
- SORT NUMBERS
- READ LIST ITEMS
- OUTPUT IN ASCENDING ORDER
- FIND SMALLEST ITEM ON ACTIVE LIST
- BRANCHING INDICATOR
- LOOP CONTROLLER

READ N

FOR K=1 TO N
READ A(K)

FOR L=1 TO N-1
LET S=10000
LET M=0

FOR K=1 TO N
S\leq A(K)
LET S=A(K)
LET M=K

M=L
LET X=A(L)
LET A(L)=A(M)
LET A(M)=X

PRINT A(L)

PRINT A(N)

Pigur* 8-32
Prom: Richards (1980 p19)
In Aristotelian logic, propositions containing two terms are classified into four kinds (A, E, I, and O) and displayed in a Square of Opposition. Propositions labelled A are universal and affirmative (All men are brave); E are universal and negative (No men are brave); I are particular and affirmative (Some men are brave); O are particular and negative (Some men are not brave). Specific relationships of truth and falsehood follow from the positions in the square of statements referring to the same two entities. Thus, if proposition A (All men are brave) is false, then its contradictory, O (Some men are not brave), must be true; while A's contrary, E (No men are brave), could be either true or false and is undetermined.
Figure 8-34
The geometry of the mind
(Celaya)
From: Ong W J 1974
New York: Octagon Books

Figure 8-35
Lessing's formula
From: McQuail D and Windahl S
1981
London: Longman p10
8.5 Variation in diagrams

Perceptual variation, as the concept is used here, has two important characteristics. One is that it can only operate within the context of similarity, otherwise we would be able to identify neither what is varying, nor even the instances within which variations are present. We would merely have unrelated difference. So again we have grouping in operation, this time to determine the instances within which variation is a factor to be noted.

Secondly, variation is, as it were, directional. That is to say, given a number of instances which contain some feature which varies by differing degrees, we are able to place them in rank order from the least to the greatest.

Variation may involve:
- orientation
- colour
- texture
- tone
- magnitude

Any progressive exaggeration of a feature, across a portion of a graphic image, is attributable to some combination of these kinds of variation. It should be noted that the term 'magnitude', as used here, refers to both extension and interval, or what we might commonly call size and distance.

In the case of a line graph, such as Figure 8-36, what is significant is the variation in the distances of data points from the axes, and the curve this produces. In the case of a bar chart, one's attention is drawn to the variation in the sizes of the individual bars. Depending on the nature of the data being handled, and the consequent conventions in operation, the distances of the bars from their parallel axis may or may not be significant. In the case of Figure 8-37, variations in the positions of the bars, left to right, are significant, representing the
progression of the months. Beniger and Robyn (1978 p7) give some early examples of what they call a 'literal line graph' and an 'abstract line graph', or what I would call a non-literal line graph. The literal line graph is that of Hauksbee (1712) and shows the hyperbolic section formed by the capillary action of coloured water between two glass plates (see Figure 8-38). The 'abstract' or non-literal line graph is that of Cruquius (1724) and shows, amongst other information, a curve representing barometric pressures (see Figure 8-39).

Beniger and Robyn (op cit pl) also give an interesting example of a graph that has a predicate space which appears to be literal in one direction and non-literal in the other, being a spatial-temporal grid (see Figure 8-40). It depicts the planetary movements by cyclic lines, and dates from the 10th or 11th century A.D. (Funkhouser 1936).

The plotting of two sets of variables, as in the examples given above, is one of the main applications of diagrams in science. If three sets of variables are involved, we need a z-axis in addition to the normal x and y-axes. Instead of our data producing a line, three sets of numbers produce a surface. If the number of variables exceeds three, making a diagram becomes difficult. However, a number of solutions to this problem have been proposed.

Thurston (1898) describes how the various strengths (or any other quality) of different alloys made from varying proportions of three metals (eg copper, tin and zinc) can be represented by a relief model. Thus four variables are diagrammed. Three of the variables are divisions of a whole and can be represented by a two-dimensional diagram. This is possible because of certain properties of an equilateral triangle; namely that the sum of the lengths of perpendiculars to the sides, from any point inside the triangle, is a constant. For example, in Figure 8-41

LO+MO+NO = PS+QS+RS. So all points inside the triangle represent any possible proportions of three constituents.
Figure 8-38
Detail from: Hawkesbee (1712 Fig 6)
Figure 8-40
From: Beniger and Robyn (1978 p1)

Figure 8-41

Figure 8-42
From: Thurston (1898 p529)
The triangle forms the base of the model and, at given points representing particular mixtures, verticals are raised. Variations in the height of these verticals represent differences in the various mixtures in terms of the particular quality under consideration.

One of Thurston's surfaces produced this way is shown in Figure 8-42.

This ingenious method does not solve the general problem of diagramming more than three variables. One solution is to use what have been called 'metroglyphs' (Anderson 1957). With a metroglyph, a set of data is represented by a graphic device which has standard features that vary in size according to the value of the variables. For example, the table in Figure 8-43 shows four individuals which have been ranked in three grades over five qualities. The qualities are represented in the metroglyph by five directions. The key is given in Figure 8-44. A high grading is a long line, a medium grading is a short line, and a low grading is no line at all. Using this method the data of Figure 8-43 can be converted into the metroglyph diagram of Figure 8-45.

Anderson (op cit pp390-391) proposes that this technique can be used for scatter diagrams, as in Figure 8-46, where two of the five qualities are represented by the position of the metroglyph on the co-ordinate graph. Alternatively they can be used as markers on maps to show the distribution of the individuals to which they refer. Anderson (op cit p389) suggests that readers can train themselves to scan such charts and apprehend 'almost immediately' the character of the data presented by the pattern of each metroglyph. '[Readers] will also see, almost at a flash...the total magnitude of the glyph.'

This would seem to be an extension of the normal technique for reading ordinary line graphs. Although the thing which determines the significance of a graph is the distance of each point plotted from the axes, it is the variation in
these distances and the consequent pattern produced which is interpreted by the reader. Users learn to recognize trends by the shape of the line, and speak of 'peaks' and 'troughs' in the data or 'steep increases' and 'slight ripples'. Over-all effects rather than individual readings tend to be noted. With the metroglyphs described above, one could scrutinize each element to determine the particular values for an individual, but metroglyphs too are designed to reveal trends. Readers might be expected to notice right-or-left and more-or-less biases in data presented in this way. There would be a tendency to group metroglyph patterns which seemed similar. The idea is that displays of this sort will show up relations which would not emerge simply by looking at tables of data, or at sets of graphs each dealing with a separate quality or separate individual.

Developments in computer techniques now make it practical to transform n-dimensional data into metroglyphs or a wide variety of other forms. Pickett and White (1966) have proposed a number of possibilities for diagramming multi-variante data. The tree shown in Figure 8-47 comprises a series of 'walks', where each walk might represent one set of variables from some experimental subject or observed phenomenon. The angle and length of each 'step' in each walk is governed by variables in the data. Pickett and White (op cit p78) suggest the, 'subjective data analyses might then be in the form of sensing and scaling some subtle features of bushiness, fullness, flexibility, fragility, etc, of the tree. Such subjective analyses of the data might well pick up effects of experimental treatments which would never be sensed in conventional analyses.'

Their (op cit p79) two other suggestions are 'straw' and 'grass'. With straw, shown in Figure 8-48, line location, orientation, and length can be determined by the variables. In this case 'softness, compactness, stiffness, etc' might be the subjective measures used to analyse the data.
In the case of 'grass' shown in Figure 8-49, five variables can be displayed on each triangular blade. Two control the position inside an unmarked cell unit. One more fixes the altitude, another its orientation, and the last establishes the width of the base. Pickett and White (op cit p80) explain that these may be extended by a further two in stereo displays, where a distance back and an angle of tilt may be included. In Figure 8-49 each blade of grass represents the admission rating and performance scores of one student from a single class of college students. The students are grouped into three equal vertical bands: dropouts on the left, regular graduates in the middle and honours graduates on the right. Pickett and White (ibid) tell us that,

'One intriguing thing that has been suggested by brief perusals so far is that honour students may be more similar to dropouts than they are to regular graduates. It is insights of this rather unexpected sort which, if they prove to be valid, would make such graphic display techniques worthwhile.'

Unfortunately the quality of the reproduction here may not allow readers to pick out the subtleties referred to.

Another proposal comes from Chernoff (1973). He uses the various features of a face, such as length of nose, size of eyes, etc, to map up to 18 variables. Figure 8-50 shows measurements taken from fossils, displayed in this manner. The subject spaces of the features are to some degree literal in their mode of correspondence, in that variations in feature size match certain measurements of the fossil they represent. Each feature is highly schematized and non-figurative. The predicate space, however, is non-literal as it does not reflect the actual distribution of the measurements. It is semi-figurative because it resembles a schematized face.

Chernoff (op cit p361) claims that these presentations 'make it easy for the human mind to grasp many of the essential regularities and irregularities present in the data'. Additionally he (op cit p364) suggests they have
mnemonic advantages. Perhaps they also allow us to use terms like 'sad', 'grumpy', or 'happy' to characterize certain classes of data!

Although all the proposals of Anderson, Pickett and White, and Chernoff are based on our ability to discern subtle differences of pattern, which in turn enable us to group related individuals, the displays themselves are based on the variation of standard elements in terms of angle, size or distance. So here again the distinction between two modes of organization becomes blurred.

Before we consider more this mixing of organizational modes, a number of examples will be given of diagrams which use variation predominantly.

In Figure 8-51 the variations in the height of the figures have a non-literal correspondence to variations in energy use at different ages. The mode of depiction is figurative and performs a synecdochical role, as the whole individual stands for an individual's energy use.

In Figure 8-52 the predicate space is semi-literal in the vertical direction, for if one could assemble a fleet of all the featured liners, theoretically their bows could be aligned as shown. The predicate space is non-literal horizontally, representing periods of time. The individual subject spaces are literal, as each schematized outline corresponds to the outline of the ocean liner to which it refers.

Because of the figurative mode of depiction used in Figure 8-53 and the fact that the subject matter is concerned with scallop shells, one might be tempted to regard this diagram as being to some extent literal. However, what the variation in the height of the piles of shells represents is a 'frequency curve'. A frequency curve is based on the distribution of a given characteristic found in a large number of observations of some phenomenon. In this case the shells have been sorted into piles according to the
Figure 8-51
From: Mitchell J (ed) 1976
Man and society
London: Mitchell
Beazley p70

At birth 48 Cal
6 months 56 Cal
1 year 54 Cal
2 years 51 Cal
4 years 47 Cal
8 years 40 Cal
12 years 36 Cal
18 years 26 Cal

Figure 8-52
From: Brinton (1914 p51)

Figure 8-53
From: Brinton (1914 p164)
number of ribs each specimen has. Left to right the piles represent the incidence of 15, 16, 17, 18, 19, and 20 ribs. There is, then, a synecdochical connection in that a whole shell stands for one of its features. As an explanation of the abstract concept of 'frequency', and the curves which represent it, this diagram could be extremely useful for instructional purposes.

The subject space in Figure 8-54 is literal, corresponding to the layout of the streets in Indianapolis in 1912. There is a sense in which the predicate sootiness is also literal, except one assumes that the soot did not distribute itself in quite such an orderly pattern in each block, or indeed in circular concentrations. Anyway, what is apparently represented by the variation in the density of dots is the relative weight of soot deposits in melted snow.

Figure 8-55 shows graphic synedoche and metonymy at work. That is, we have a part standing for the whole and the substitution of associated objects. In this case babies stand for births and coffins for deaths. The predicate space is semi-literal if we are dealing with babies and coffins, which could be arranged as shown; however, births and deaths cannot be lined-up, therefore the content model is non-literal. The important thing for present concerns is that it is the variation in the lengths of the rows which tells the story.

Figure 8-56 uses the variation in the size of sectors to show the distribution of family income. The mode of correspondence of the content model with what is represented is non-literal. The figurative elements act as extra labels as well as decoration, but unfortunately they do not assist the reader to judge relative allocations, as Brinton (1914 p6) points out. Pie charts can be difficult to read - especially when there are many thin slices. (This also creates labelling problems.) However, they do have the merit of being quite clearly divisions of wholes.
In Figures 8-57 and 8-58, readers must take into account variations in three-dimensions. Both diagrams are essentially non-figurative although Figure 8-58 might be taken to be an iceberg. The mode of correspondence is non-literal in both cases, with the exception of the vertical dimension which could be contrived by piling up the money, and the people, respectively.

In some diagrams no single mode of organization is as strongly in evidence as in the examples given here. The more mixed modes will be considered next.
Figure 8-57
From: Brinton (1914 p337)

Figure 8-58
From: Head W R (1968)
An economic geography of the Scandinavian States and Finland
University of London Press p73
As noted earlier in this chapter and illustrated in Figure 8-8, the modes of organization are not discrete categories and it may be argued that they are present in varying strengths in all diagrams. What we take to be significant will be directed, in varying degrees, by convention. For instance, no significance is attached to the variation in the length of lines linking events in a standard critical path diagram, whereas in other sorts of planning chart such variations may indicate differences in the amount of time elapsed. In one diagrammatic context similarity of colour may group elements together, whereas in other situations such correspondences may be incidental. So the modes of organization may operate differentially as a consequence of convention, both between and even within diagrams. For instance, variations in one dimension of diagram may be significant, while variations in another may not. A bar chart of the populations of various cities would illustrate the point if the left to right sequence of bars was arbitrary. Only variations in the vertical direction would have meaning.

Because of the arrangement of their parts, and to some degree the operation of convention, the modes of organization in diagrams may appear in varying mixtures.

Consider Figure 8-59. In this diagram all three modes of organization are clearly in evidence. It would seem to be a combination of a graph (where the horizontal axis is insignificant), a Venn diagram (where the variation in size of the circles does have meaning), and a flow chart.

Figure 8-60 combines grouping with variation in its content model. The two-way classification of counties against category headings relating to women and work forms the horizontal matrix of the subject space. The matrix groups the columns which vary in height according the various values in the predicate space.
Figure 8-59
From: Newton (1964)
Figure 8-61 on the other hand combines linking, which shows the sequence of destinations, with variations in the shaded areas running parallel to the routes. These shaded areas indicate the density of the freight traffic travelling on the lines to which they are attached.

The descriptions of diagram specimens given in this chapter have been in rather general terms, and have dealt with overall impressions. In the next chapter a more detailed process of analysis will be reported. In some cases, the modes of organization are less evident on cursory examination. The purpose of the method of analysis proposed in this dissertation is primarily to reveal the modes of organization present in diagrams.
The term modes of interpretation was introduced for referring to the modes of correspondence, depiction and organization collectively.

The principal taxonomical model proposed in this dissertation was introduced. This model shows the relationship between the modes of interpretation.

It was pointed out that as one moves away from the figurative and literal mode of depiction towards the non-figurative and non-literal, so the modes of organization tend to be restricted to three main types. These are grouping, linking and variation. This is one of the principal findings of the study reported here. Various specimens were examined to illustrate this point.

The modes of organization are not to be thought of as discrete categories, and they can be used in various combinations.

Various diagram specimens were examined to illustrate the presence of the three modes of organization.
Chapter 9  AUDITS OF SPECIMEN DIAGRAMS

9.1 Classification of relational features

9.2 The auditing process

9.3 Audit of the 'History of Miyano' diagram

9.4 Audit of the 'Mental personality' diagram

9.5 Comments on the diagram audits

Summary

From: Daily Mail 4th April 1982
In Chapter 3 the idea that diagrams could be analysed into their significant elements was introduced. Using these elements as the primary units of analysis it is possible to carry out what might be called a, diagram audit.

In this chapter the audit technique will be described in some detail and an account given of its application to two specimen diagrams. The technique provides a systematic approach for scrutinizing diagrams. The aim is to minimize the possibility of overlooking any characteristics of significant elements which contribute to the relational meaning of a diagram. The purpose of the audit process is to isolate the three modes of organization, identified in this work as present in diagrams which are primarily non-literal and non-figurative. To do this it is necessary to extend the process of analysis introduced in Chapter 3.

A single significant element may contain several characteristics, each capable of having different relational meanings ascribed to it. These characteristics will be termed, relational features.

For example, a group of significant elements may be connected by a line which changes colour as it progresses from element to element. Change in colour might be interpreted as indicating some change in status of the connected elements. In this case the line would have two relational features. One is the property of linking between the elements, and the other is the variation in colour representing some gradual change in status. So significant elements may have a mixture of organizational modes through having more than one relational feature.

It is not inevitable that a significant element has more than one relational feature. If, in the example just given, the line exhibited no variation along its length, it
would have only the linking mode of organization. It is also possible for a significant element to have two features which have essentially the same meaning and are thus complementary. This may be termed 'redundant recoding' [1]. For instance, as the bars of a histogram increase in length so they might increase in, say, intensity of redness. Here two sorts of variation reinforce each other.

This example also illustrates another useful distinction, that is the one which may be drawn between, intrinsic and extrinsic features. The increasing intensity in redness is a feature intrinsic to the significant elements which are the bars of the histogram. In fact the patch of colour of varying hue may be the only thing which defines the bars. There may not be, for instance, an enclosing outline. Features which are physically part of the significant element are intrinsic to it. This is not to say that it is impossible to separate features from their elements conceptually. In this example we might well regard the bars of the histogram as being characterised by their shape and occupying noun spaces, while the varying insensities of redness may be thought of as a property of some separate verb space.

On the other hand, extrinsic features are those which are, as it were, not an identifiable characteristic of individual elements, but are properties of groups. This includes all spatial arrangements such as grouping by proximity, or rankings established by variations in size as in the histogram example.

So the significant elements occupying noun spaces are those that represent the things about which the diagram purports to say something. Relational meaning can be inferred from both their intrinsic and extrinsic features, which may be thought of as occupying separate verb spaces. It should be noted that it is therefore not necessary for the verb spaces of a content model to actually contain any
significant elements performing a verb-like function. Often the verb spaces, as it were, perform an organizing function on the noun spaces. But the significant elements occupying noun spaces may also be organized by other significant elements which do occupy verb spaces. These elements in the verb spaces take their meaning from the relations they impose on the noun space elements. Without the noun space elements we do not have anything the diagram can be about. Without the relational features of the verb spaces no relations are exhibited.

In the same way that diagrammatic noun spaces may serve as either subjects or objects in the grammatical sense, so it could be in some cases that significant elements may function either as nouns or verbs. However, the less a graphic display is susceptible to being analysed into spaces which serve noun and verb-like functions, the less likely we are to have a diagram. This follows if, as I assert, exhibiting relational information is a defining characteristic of a diagram.

The extended process of analysis outlined above may be represented as shown in Figure 9-1, which is a development of Figure 3-14.

To recapitulate, a diagram depicts a content model which can be analysed into various distinct spaces serving either noun or verb-like functions. These spaces will contain one or more significant elements which in turn may have one or more relational features. Each significant element will have its mode of correspondence and depiction, and each relational feature will have its own mode of organization. The mode of correspondence may be literal, semi-literal or non-literal. The mode of depiction may be figurative, semi-figurative or non-figurative. In the case of the non-literal and non-figurative modes, the mode of organization can be that of grouping, linking and variation. The relationship between these possibilities can be illustrated by combining Figures 8-2 and 8-9. This is shown in the taxonomic model in Figure 9-2.
Figure 9-1
(a development of Figure 3-14)

Graphic display

Content model

Subject space

Predicate space

Object space

Noun space

Verb space

Significant element

Relational feature

Intrinsic feature

Extrinsic feature
Figure 9-2

Key

Modes of correspondence
- Literal
- Semi-literal
- Non-literal

Modes of depiction
- Figurative
- Semi-figurative
- Non-figurative

Modes of organization
- Grouping
- Linking
- Variation
It has already been stressed that the various categories displayed in this model should not be regarded as being discrete. Each should be thought of as merging into the next. It is only a matter of convenience that this model is shown as three disks. A better way to think of it is as a column of some medium which, say, changes tone, from dark to light, in an upward direction and becomes increasingly more coloured towards its periphery. The three primary colours could represent the three modes of organization, and all the mixtures this produces would represent all the possible relations between various modes of interpretation. Depending on its classification, each relational feature of a significant element in a given content model, would have a particular location (and consequently colour) in the classificatory space defined by the column.

Looking at Figure 9-2 we see that, depending on the direction of schematization, the man, the woman, and the dog may be represented in terms of their groupings (one outline grouping the two on the dia, and one outline enclosing all three), their linking (between the woman and dog), and their variation (in relative sizes).

The depictions of the man, woman and dog stand on the non-literal plane and should, therefore, not be taken to represent a man, a woman, and a dog. They might, for example, represent the relations between two countries and some satellite state. This same illustration, and its non-figurative derivatives, could have been on the bottom plane, in which case it would literally represent a man, a woman, and a dog.

It will be noticed that the middle group are slightly off-centre; this is to allow for the fact that the depiction here is not as figurative as is possible.

This taxonomic model encapsulates the thesis presented in this dissertation. It represents the contribution this work makes to our understanding of diagrams.
In the next section the scheme of analysis and classification used for the diagram audits reported in this chapter is described.
For the purposes of the process of analysis and classification proposed here it is not necessary to distinguish between noun space and verb space elements. All that is necessary is that elements, or classes of elements, are identifiable. However, in the analyses of specimens which follow, I have made it a practice to deal first with those elements which may be regarded as belonging to noun spaces.

The process of auditing each diagram has the following stages:

1. Analyse the content model into significant elements or classes of significant elements.

Taking each element, or class of element, in turn:

2. Classify its modes of correspondence and depiction.

3. Classify the intrinsic relational features in terms of their modes of organization.

4. Classify the extrinsic relational features in terms of their modes of organization.

In all the diagrams analysed, each significant element, or class of elements, will be assigned a letter of the alphabet and each of its features will be given a number. It will be seen from the specimen analyses that sometimes different features can have the same general meaning, but of course each feature will be dealt with separately. It will also be seen that sometimes a single feature can have more than one relational meaning, and hence exerts more than one mode of organization on its part of the diagram. Where this is the case, each mode of organization will be listed under the same feature code number.
It might be noted that intrinsic features may express
relations which seem to be particular to significant
elements, or to the class of elements to which they belong,
such as, say, showing some gradual variation in width to
indicate some gradual change in status. Other intrinsic
features may denote more general characteristics such as
membership of some superordinal category. For example, an
element might belong to the class of all green elements in
a diagram. In the following analyses I have adopted the
practice of moving from the more particular to the more
general when dealing with features.

An important part of a diagram is the labelling of
elements, and it is this which often determines the meaning
we confer upon it. Two content models which otherwise
might be taken as similar can have entirely different
meanings when labelled. However, it is my thesis that at
the most general level of meaning they must be the same.
For example, two elements may be connected by a line. If
we are to take this as significant at all - and labelling
may play a part in determining this - the meaning at the
most abstract level of interpretation is that the two
elements are linked in some way. Labelling might help us
tell whether the link is a river, a wire or, say, a kinship
tie. As we are here concerned with establishing the
organizing principles of the most schematized and
non-literal type of diagrams, it is the meaning at this
most general level which is of interest. Consequently, for
the purposes of this analysis, labelling will be omitted.
That is to say that where
'symbolic coding'
is used to identify
'perceptually coded' elements
- to use the terminology of Fitter and Green (1979) - it
will not form a constituent in the process of analysis
described here. To exemplify the difference between a
perceptual code and a symbolic code, Fitter and Green (op
cit p238) compare a map 'which presents its information
coded into the dimension of spatial location, with a list
of grid references'. They point out that the difference
defies simple definition and suggest (ibid) that, 'One might argue that symbolic representations require conscious cognitive processing, whereas analogical or pictorial information is perceived immediately, but AI [artificial intelligence] and cognitive psychology have shown us that one cannot make a sharp distinction between perception and cognition. Luckily, everyone knows what we mean when we say information can be presented in a perceptual code!' 

Perceptual codes are those which do not seem to rely entirely on some pre-established conventional correlation between their visual characteristics and their meaning. It is argued here that this is a consequence of our being able to recognise similarities between diagrams and our experience of the visual world in general. This recognition enables us to make a transference of meaning which seems best described as metaphoric. In this respect the term 'code' is perhaps not entirely satisfactory when used in association with 'perceptual'. This idea of course runs counter to the arguments of others, described in Chapter 4, that all pictures comprise only 'labels', the meanings of which are entirely a matter of convention. This view would not permit the distinction made here between the perceptual and the symbolic, or the kind of classifications given in Twyman's (1982) model shown in Figure 9-3. This model explains the derivation of the term 'Verbal Graphic Language' which enables a distinction to be drawn between writing and machine-generated text taken together, and other symbol systems which come under the 'schematic' heading. Symbol systems of this sort are, as it were, more local than verbal graphic language and generally require a key when used on diagrams. Both sorts may be used for labelling diagrams.

Now, there can be cases where labels in the form of verbal graphic language can serve as both symbolic and perceptual codes. In these instances, labels can be taken as a significant element for the purposes of analysis.
Figure 9-3
From: Twyman (1982 p7)
For example, a map may show towns as spots, next to which the towns' names are placed as labels. Here the spots would be taken as elements in the noun space, while their labels would be omitted from the analysis. On the other hand if the labels themselves marked the location of the towns and no other markers were used, the labels would be regarded as significant elements in their own right. In a similar way a word, or a phrase, might connect two elements. In this case also, verbal graphic language would perform the function of a perceptual code. It would be an element in a verb space and would count as a significant element, unless it labelled some other significant element which had that linking function itself. It should be noted, however, that even in the case where a label is not featured as an element in an analysis, it can have intrinsic diagrammatic meaning. For example, differences of style or colour may indicate differences of content, and where such relational meaning is not otherwise expressed, it will be deemed to be part of the significant element labelled. This could even include the grouping mode of organization created by elements being labelled, as distinct from those which are not.

Finally, the background is always included as a significant element as a matter of course, in order to avoid its omission in those cases where it may carry relational meaning. For example, it might be shaded light to dark as a means of conveying the idea of some gradual change in some dimension.

The application of this auditing process to two specimen diagrams will be described next in this chapter. Additional analyses are given in Appendix B.
9.3 Audit of the 'History of Miyano' diagram

This diagram was used in Chapter 3 in order to illustrate the process of analysis proposed in this dissertation, and it appears again here as Figure 9-4. It represents the history of the Miyano company by showing what might be described as a family tree of its products combined with a time chart. Its content model can be analysed into 26 classes of significant elements including the background. These are:

A  Yellow machines
B  Grey machines
C  Machine of 1948
D  Files
E  Spark wheels
F  Background
G  Vertical flow lines (tapered)
H  Horizontal flow lines (arrowed)
I  Horizontal dividing lines
J  Small black spots
K  Small black stars
L  Large black spots
M  Large black star
N  Green spots
O  Small red date
P  Large red dates
Q  Large orange headings in Japanese
R  Black column headings (Japanese)
S  Black column headings (English)
T  Captions near machines
U  Captions near large black star and spot
V  Captions near files & spark wheels (date & Japanese)
W  Dates (Japanese)
Y  Captions to horizontal rows (code numbers)
Z  Captions to horizontal rows (description)

Each depiction of a product is taken to represent a token example of the firm's production of a particular type or model. The total range of models represented stands for the
Figure 9-4
(also Figure 3-9)
history of the firm. So we have individual specimens synecdochically representing the firm's production, which in turn metonymically represents its overall development. However, for the purposes of analysing the relational meaning expressed by the diagram, it will be assumed that each image simply represents an individual specimen of the product it depicts.

A Yellow Machines

The mode of correspondence between these elements and what they represent is literal and the mode of depiction is fairly figurative.

Intrinsic features

A1 The illustrative treatment of these images, having the character of outline drawings, tends to group them with those treated similarly; namely the grey machines.

A1 Although these significant elements are all different in some detail, they are all recognisable as pieces of machine tool equipment. In this respect they group themselves with the grey machines, and less strongly with the machine of 1948, mainly because of the difference in illustrative treatment.

Extrinsic features

There do not appear to be any extrinsic relational features.

B Grey machines

What goes for the yellow machines goes, mutatis mutandis, for the grey machines.

C Machine of 1948

Miyano's first piece of machine tool equipment is standing in half a broken egg-shell which presumably represents the
birth (or hatching!) of a new phase in the company's growth. The egg-shell is a metaphorical ingredient and not some form of packaging, although it would be possible to stand a machine inside a giant egg and such things are done at trade fairs. On this basis the mode of correspondence is semi-literal. The mode of depiction is, however, quite figurative.

Intrinsic features

C1 The bluish colouring tends to group this element with the files and spark wheels.

C2 As in the case of A3, one may well recognise part of this element as a piece of machine tool equipment and would probably group it with the other machine tool depictions.

Extrinsic features

There do not appear to be any extrinsic relational features.

D Files

Although this element represents several files and some catalogues, the strong unity of the image inclines one to take it as a whole. The mode of correspondence is literal and the mode of depiction is quite figurative.

Intrinsic features

D1 As with C1 the illustrative treatment performs a grouping function.

Extrinsic features

D2 The files, and the spark wheels, appear to detach themselves from the other noun space elements and group together by proximity. This separation could mark a distinction between the original output of the firm and its later, more prestigious products. It could be of course
that this detachment is in part a matter of convenience, used to avoid having the image of the spark wheels straddle the gutter of the publication in which the diagram appears.

E Spark wheels

What goes for the files goes, *mutatis mutandis*, for the spark wheels.

P Background

In this case the background considered alone is insignificant.

G Vertical flow lines (tapered)

The pattern made by the flow lines could suggest a highly schematized tree, and the attribution of growth would be regarded as a positive aspect of this metaphor. The periods of more recent development are represented by flow lines of a lighter green, which is the coloration one might expect to see in new growth on plants. The increase in the width of the branches towards their extremities however may not correspond to one's expectations of actual trees and perhaps might fit the notion of river systems better. In this case the flowing of water might represent metaphorically the passage of time. Anyway, no one interpretation presents itself strongly and, as a consequence, all these elements can be classed as non-figurative. As the flow lines do not represent any literal connection between the elements they join, the mode of correspondence is non-literal.

Incidentally I might observe that our interpretation of these particular elements is perhaps helped by a familiarity with the evolutionary trees used in natural history, thus convention plays a strong supporting role.

Intrinsic features
The flow lines link the various machines, establishing the sequence in which they came onto the market.

The flow lines group the machines together into families under the various headings.

Significance may be attached to the variation in the widths of the flow lines. As they 'rise' up the diagram, so they increase in size, matching the increase in the time elapsed and, perhaps, suggesting an increase in production and growth of the company.

The gradual variation in the colour of the flow lines parallels the gradual increase in their width, and may be thought to have similar significance in so far as it suggests some gradual change. It may also be taken as a colour coding, grouping together machines attached to flow lines with similar coloured backgrounds and hence belonging to a similar stage in the development of the company.

There may be said to be a passing similarity between the vertical flow lines and horizontal flow lines. This serves a grouping function, indicating a similarity of purpose.

Horizontal flow lines (arrowed)
These flow lines are similarly non-literal and non-figurative. They use the arrow convention to indicate direction.

They link products thus establishing their temporal sequence.
Having a different shape from the tapered flow lines and a different orientation, they reinforce the grouping of the 1948 machine and the pre-1948 products.

The variation in the length between the two flow lines seems to be of no significance and is in fact in inverse proportion to the periods of time separating the items to which they relate. This would appear to be for reasons of convenience, already mentioned in D2.

I Horizontal dividing lines

These non-literal and non-figurative elements form a verb space which imposes a temporal dimension on the content model. They de-neutralize the background (F) and impose an order on an otherwise insignificant space.

Intrinsic features

There are no intrinsic relational features.

Extrinsic features

I1 The divisions created by the lines group together products of a similar period, both with each other and with the relevant captions. Of particular importance here is the association with the dates shown in red, which are given considerable prominence over the other labels and emphasize the time-chart character of the diagram.

I2 The variations in the distance of the lines from the bottom of the diagram represent the progress of time and thus divide the content model into a number of equal horizontal zones, one for each five year period.

Labelling

The rest of the elements in this diagram may be regarded as performing what are essentially labelling functions.
9.4 Audit of the 'Mental personality' diagram

Figure 9-5 shows Freud's (1933) diagram of the mind. Freud applied the terms 'province', 'realm', or 'region' variously to the super-ego and id [2]. He pointed out that these regions do not coincide exactly with the three qualities of mental activity, namely: 'conscious', pre-conscious' and 'unconscious'. To make the point Freud (op cit pp97-98) invites us to:

'...picture a country with great variety of geographical configurations, hills, plains and chains of lakes, and mixed nationalities living in it...engaged upon different occupations...Now the distribution might be such that the Germans lived in the hills and kept cattle, the Magyars on the plains and grew corn...(etc.) If this distribution were neat and exact it would...be convenient for giving a geography lesson. It is probable, however, that you would find a less orderly state of affairs if you visited the region...The picture of the region which you had brought with you might on the whole fit the facts, but in details you would have to put up with the departures from it.'

So in a similar way, he (op cit p100) observes that the id has other characteristics besides being unconscious, and that part of the ego is unconscious without possessing the same primitive and irrational quality of the id.

Freud (op cit p97) wished, then, to distinguish between 'the three qualities of mind...and the three regions of the mental apparatus...'. Taking the two classes of territory represented in the diagram and omitting the repressed region for the moment, we may construct a separate diagram for each. Figure 9-6 shows the qualities of mind. Figure 9-7 shows the mental apparatus. Without the indication of a boundary between the ego and id, which is perhaps suggested by the 'repressed' barrier in the complete diagram, one must imagine the territory of each extending outwards from their respective labels and merging together. This is an
self-reflective functions.' Betelheim (Symington 1983) has pointed out that 'ego' and 'id' are Latin translations from Freud's original German 'Ich' and 'Es', which in English mean 'I' and 'it' respectively. Had the translators used English we would now speak of 'the I' and 'the it' and not 'the ego' and 'the id'. Betelheim claims that this introduction of Latin into the English translation has denuded Freud's writings of all emotionality. I must say that this revelation has made Freud clearer for me.

Figure 9-6

Somewhere at this merging interface, and shading into the id, is where the repressed material would appear if it were included. Recombining Figures 9-6 and 9-7 we see we have something akin to a Venn diagram with overlapping regions. The major difference is that in this case the boundaries are to be thought of as fuzzy. So, in addition to the separate areas of the diagram they are supposed to occupy, the distinction between mental qualities and apparatus is matched by a distinction in the presentation of their labels. This seems to be a graphical cross reference to geographical maps, where different typographical styles correspond to different classes of territory.

Freud's topographical terminology and territorial metaphor might lead us to regard his diagram as a kind of geographical map. However, we know from his commentary (op cit p104) that it is not intended as a plan of cerebral anatomy, but represents the functional relations within the mental personality. Indeed, in Appignanesi and Zarate (1979 p155) the reproduction of the diagram bears the annotation:

'It's a diagram of your desires - not a map of the brain.'

This diagram is, then, essentially a spatial metaphor rather than a literal picture. The content model is therefore classed as non-literal, with the exception of some features which will be pointed out later. It is perhaps worth noting that, in spite of not representing
locations in the brain, the profile of the diagram has an organic character and is even vaguely head-shaped.

This organic appearance is more marked and more suggestive of a brain in an earlier version of the diagram (Freud 1961 p24), included here in Figure 9-8 for comparison. However, other likenesses may be observed which may be more or less appropriate. For example, compare Figure 9-9 with Figure 9-5. Freud's diagram will be taken as non-figurative, although it is possible that other diagrams which are figurative may have influenced its design. Consider Figure 9-10 for instance.

The content model of Figure 9-5 may be analysed into the following significant elements:

A

Labels in large capitals

B

Label in small capitals

C

Labels in lower case

D

Background

E

Left and right outer curved lines

F

Inner curved line

G

Upper curved line

H

Horizontal dotted lines

I

Angled parallel lines

The elements A, B and C are in the form of verbal graphic language, but in addition to their labelling function they also act as noun space elements, so they will be included in this analysis.

A

Labels in large capitals

Intrinsic features

A1 Because of the similarity of form we tend to group these labels with the 'SUPER-EGO' label set in small capitals and to disassociate them from those set in lower case.

Extrinsic features
A2 The near alignment of the "EGO" and "ID" label reinforces their particular group membership.

A3 The variation in size between all the labels in the diagram places the ego and the id at the top of the hierarchy.

B Label in small capitals

Intrinsic features

B1 Because of the similarity of form we tend to group this label with the labels set in larger capitals and to disassociate them from those set in lower case.

Extrinsic features

B2 The parallelism of this lettering with the inner and outer left-hand curved line tends to form a group of these elements.

B3 The proximity of the small capitals with these other elements also tends to have a grouping effect. Only the grouping with the inner curve described in B2 and E3 would seem to be of significance as it is the boundary of the territory to which the label belongs.

B4 The more or less vertical orientation of this label serves to reinforce its grouping with the other labels set in larger capitals, which also have a near vertical orientation.

B5 The variation in size between the labels of the diagram places the super-ego in the middle of the hierarchy.

C Labels in lower case

Intrinsic features

Cl The labels in lower case tend to form a single group by virtue of their similarity of form.
Extrinsic features

C2 The labels set in lower case form two sub-groups; that is, those which are horizontal and the one which is not.

C3 The variation in size between the labels of the diagram places these at the bottom of the hierarchy.

D Background

In this case the background considered alone is insignificant.

E Left and right outer curved lines

Intrinsic features

E1 The curved shape of these lines is one of the features which establishes the class to which it belongs, but also groups it with the other curved lines in the diagram.

E2 The linking with the upper curved line also establishes the group of lines which forms the outline enclosing boundary of the diagram.

Extrinsic features

E3 The enclosing curves mark out the territory representing the mind and serve to group together the various areas into which Freud divided the mental apparatus of the individual. Conversely, the boundary tends to disassociate its contents from the outlying areas of the diagram, which I assume represent the external world. If this is the case, then these curves are candidates for the semi-literal category. This is because whatever external forces may be involved in shaping the psyche of an individual, the mental apparatus is contained within that person, and both an individual and the content model have
the corresponding qualities of insideness and outsideness.

E4 The parallelism of the left-hand curved line with the line of the label in the small capitals and with the inner curved line tends to form a group of these elements.

E5 The proximity of the left-hand curved line with these other elements also tends to have a grouping effect. E4 and E5 do not seem to have any particular significance.

E6 As well as enclosing the territories of the mind, the outer curved lines seem to emphasize the general topology of the various territories established by the labels. The linking of the different areas of the diagram is determined by the intimacy of the functional relations and their origins in the developmental process of the psyche. For example, the ego is linked to the id, out of which it developed. We know that the ego 'mediates between the id and reality' (Freud 1933 p103), and that information regarding the external world comes from the perceptual-conscious system. The sequence of these parts as shown in the diagram, then, matches their functional relations.

In one respect there is also a fairly literal correspondence with the physical structure of the brain and the supposed location of certain mental activities. The top of the diagram contains the apparatus dealing with perceptions and consciousness. In current theory concerning brain physiology the processing of perceptions and conscious activity is believed to occur near the surface of the brain, whilst the more primitive and unconscious processes are ascribed to the deeper regions. In the diagram, too, the id and the unconscious territories are ascribed to the deeper regions and are placed at the bottom. If account is taken of the linking of territories on the vertical axis and the correspondence of this linking with the distribution of brain functions, one could make a case for semi-literal classification here.

With regard to the fact that the outer curved lines do not
entirely enclose the various territories of the mind as they do in the earlier version (cf Figure 9-4), Freud (op cit p104) tells us that,

'The space taken up by the unconscious id ought to be incomparably greater than that given to the ego or to the preconscious. You must, if you please, correct that in your imagination.'

I presume that the gap in the outline at the bottom of the diagram is to allow for this expansion.

F Inner curved line

Intrinsic features

F1 The curved shape of this line tends to group it with the other curved lines in the diagram although this seems to be of no particular significance.

Extrinsic features

F2 The parallelism of the inner curve with the outer curve and the line of the label in small capitals tends to form a group of these elements.

F3 The proximity of the inner curve with these other elements also tends to have a grouping effect. Only the association with the label described in B would seem to be significant. This association is that between a label and the boundary marker of the territory to which the label refers.

F4 The inner curved line groups together the territory of the super-ego and this disassociates it from other regions. Freud (op cit p104) directs us to,

'...observe how the super-ego goes down into the id; as the heir to the Oedipus complex it has, after all, intimate connections with the id.'

The arrangement of this feature in the diagram is quite suggestive of a pathway leading from the unconscious to the preconscious, but this is not intended. We are merely to
think of the super-ego occupying a general location relative to other regions. This is clear from the warning that when,

'...dividing up of the personality into ego, super-ego and id, you must not imagine sharp dividing lines such as artificially drawn in the field of political geography.' (op cit p105)

F5 The function of the Y-shaped ends of the inner curve is unclear and is possibly an attempt to indicate that the boundary does not have precise terminations. Hence the grouping it represents is indirect.

F6 The variation in the size of the territory marked off by the inner curved line, being smaller than that of the ego and the id, indicates its secondary role.

When Freud deals with the way in which the super-ego takes over parental guidance we are told:

'The super-ego seems to have made a one-sided selection, and to have chosen only the harshness and severity of the parents...' (op cit p85)

It is interesting to note that this 'one-sided' metaphor is carried through into the diagram, with the super-ego being displayed as offset to the left.

G Upper curved line

The uppermost curve presumably encloses the region of the 'perceptual-conscious system', although, as the label is placed outside the enclosed area, this is not too clear. Freud characterizes this system as 'the most superficial portion of the mental apparatus'. It is,

'...directed on to the external world, it mediates perceptions of it, and in it is generated, while it is functioning, the phenomenon of consciousness.'

(op cit p100)

The profile of the upper curve, together with the other enclosing curves, is quite suggestive of an eye, which is the organ which seems to dominate our ideas of perception (cf Figure 9-10).
Given the non-literal character of the diagram, any such resemblance can be at most only a cross-reference, particularly as this element represents a system which is, '
...the sense organ of the whole apparatus, receptive
moreover, not only of excitation from without but
also of such as proceed from the interior of the
mind.' (ibid)

Anyway, our perceptions of the world are not limited to vision. It is of interest to note that in the earlier version of this diagram (Figure 9-8) 'the ego wears a "cap of hearing" on one side only, as we learn from cerebral anatomy' (Freud 1961 p25). This seems to be an attempt at a more literal correspondence with the supposed distribution of brain functions. The later diagram, considered here, omits this detail.

As to the position of the label above the curve, this may be to stress the superficial nature of the perceptual conscious system by its close association with the area of the diagram representing the external world, or it may be simply the practical difficulty of fitting it into the confined space available. Labelling the acoustic zone on the earlier diagram apparently presented the same problem. Anyway it seems to me unlikely that the perception-conscious system should be understood to be the area outside the curve. In accordance with the principles of gestalttheorie one may be tempted to mentally complete the circle, of which the uppermost curve is part, thus enclosing the territory I take to be that of the perceptual-conscious system. The ghostly outlines which project beyond the ends of the curves, after they cross like the poles of wigwams, may suggest to the reader areas of indefinite extent. This, as already mentioned, is how Freud invites us to consider the territories of the diagram with more visible boundaries.

Intrinsic features

G1 The curved shape of this line tends to group it with the other curved lines in the diagram.
G2  The linking with the left and right outer curved lines establishes the group of lines which forms the enclosing boundary of the diagram.

Extrinsic features

G3  The upper curved line serves a grouping function as it encloses the territory of the perceptual-conscious system. It is a candidate for the semi-literal category for the same reasons as are given in E3.

G4  The area marked off by this element is relatively smaller than that of other territories and this variation presumably indicates that a smaller part of the mental apparatus is given over to the perceptual-conscious system.

H  Horizontal dotted lines

Intrinsic features

H1  The graphical character of this boundary seems to distinguish it from other boundaries. By transferring this graphical distinction, between the respective boundaries, to the regions they group, we may infer that the divisions between, say, the ego and the super-ego are of a different nature from those between conscious and preconscious. This is borne out by Freud's commentary.

Extrinsic features

H2  The double, dotted appearance of these dividing lines is presumably supposed to suggest an indistinct grouping of preconscious and unconscious territories. It will be noted that the 'EGO' label straddles the lines and, we know from the commentary, that part of the ego is unconscious.

I  Angled parallel lines

' The ego has separated itself off from one part of
the id by means of repression-resistances. But the barrier of repression does not extend into the id;...' (Freud 1933 p103)

When one is familiar with the theory represented in this diagram, one is perhaps slightly inclined to see this element as, say, a lever which is pivoted at its extreme right-hand point. Whilst once parallel with the horizontal dotted lines, it has now been pressed (or repressed) downwards.

Intrinsic features

I1 Here also I assume that the different graphical character of the lines used serves to differentiate them from lines serving other kinds of grouping and separating function.

Extrinsic features

I2 The double, continuous lines represent 'the barrier of repression' which serves to group together the repressed material and separate it from the area of the ego.

The label 'repressed' is aligned with the barrier and appears very close to it. This seems to serve the function of naming the barrier itself, for if it were indicating the repressed material one would expect the label to be underneath, 'so that the repressed material merges into the rest of the id' (op cit p103). This is in fact how the label does appear in the earlier version of the diagram (Figure 9-8). It is interesting to note in this earlier version that the 'repressed' barriers look more like a roadway open to the external world. The reasons for this are unclear. Freud's (1961 p24) commentary on the earlier version includes the disclaimer:

'The state of things which we have been describing can be represented diagrammatically...though it must be remarked that the form chosen has no pretensions to any special applicability, but is merely intended to serve for purposes of exposition.'
Some comments on this, and the other audits described in this dissertation, are given next.
A considerably less detailed examination than is described in this chapter was applied to the 550 specimens in the original sample of diagrams collected for this study. This less detailed examination suggested that the less literal the mode of correspondence, and the less figurative the mode of depiction used in a graphic display, the more evident the modes of organization identified in this dissertation appeared to be. Conversely, the more literal, and the more figurative they are, the more other sorts of visual relations appeared to come into play.

The process of auditing was devised to provide a more precise method for scrutinising diagrams. It has been applied to a number of diagrams taken from the original sample. Accounts of two of these audits have just been given and the rest appear in Appendix B.

The purpose of the audits was to further test the thesis concerning the presence of the modes of organization and their relation to the modes of correspondence and depiction. The audits conducted as part of this study are judged not to reveal any significant challenge to this thesis.

Some comments on the audits are now given.

The diagrams to which the audit process was applied were selected because they represented a range in terms of both complexity and style. The 'History of Miyano' diagram and the 'Mental personality' diagram were selected from the others for inclusion in this chapter as they both presented interesting problems of analysis and classification. The 'Mental personality' diagram is also interesting from the point of view of historical importance.

In the 'History of Miyano' diagram the significant elements A to E appear to be literal and figurative, with the
exception of C which is semi-literal. These significant elements perform the function of markers within the diagram. In terms of its relational meaning this diagram would function just as well with non-literal and non-figurative elements in the place of the figurative and literal, or semi-literal markers. The relations amongst these elements are non-literal and the rest of the significant elements in this diagram are non-literal and non-figurative.

The 'mental personality' diagram is also essentially non-literal and non-figurative, with perhaps, the exception of element E which might be classed as semi-literal (see E3 and E6 of Section 9.3).

The relational meanings expressed by the significant elements of both of these diagrams are largely those concerned with the ideas of association, sequence, and value. These diagrams, then, illustrate the association between the non-literal and non-figurative modes and the modes of organization; namely grouping, linking, and variation.

Now I have proposed that the more literal the mode of correspondence, and the more figurative the mode of depiction used in a graphic display, the less evident the modes of organization of grouping, linking, and variation tend to be. Some examples of this may be seen in the additional audits given in Appendix B. The 'Sensory homunculus' for example, dealt with in Section B.1, is in some degree both literal and figurative. This graphic display has significant elements which do not merely express ideas of association, sequence and value. They express other relations. These are to do with such things as location and shape. With Section B.1, the classifications B1, C1, C3, C4, D2, and D5 indicate this.

The 'Diagram of lines' in Section B.2 of Appendix B gives other examples. This diagram is essentially non-figurative; however, the mode of correspondence is to
some extent literal. Whilst this diagram mainly makes use
of linking and grouping, one cannot discount the effect on
our understanding created by the visual relations of
location and shape which are present. See the
classification of A4 and D1. Location and shape are of
course present in all diagrams, but the operation of
convention, which relates the diagram to its referent,
determines whether significance is attached to these
features. On the other hand, combinations of association,
sequence, and value seem to be the essences of the messages
expressed by the diagrams of B.3, B.4 and B.5 in Appendix
B. Here the organizational modes of grouping, linking, and
variation are strongly in evidence.
Summary

The process of analysis introduced in Chapter 3 was extended to include relational features which may be intrinsic or extrinsic.

This extra level of analysis is necessary in order to carry out a diagram audit. The purpose of the audit process is to isolate the three modes of organization identified in this work as present in diagrams which are primarily non-literal and non-figurative.

A spatial model was introduced which shows the relationship between the modes of interpretation. This model encapsulates the thesis presented in this dissertation.

A detailed description was given of the process of auditing a diagram. Using this technique a number of specimen diagrams have been analysed and their significant elements and relational features classified. Accounts of two of these audits were given.

Some comments were given on these two audits and on those contained in Appendix B.
10.1 The nature of diagrams

10.2 Relations between the interpretive modes

10.3 Value of the figurative and non-literal modes

10.4 Implications for diagram designers

10.5 Future Research

Summary
This chapter sets out to review the thesis presented in this dissertation and to look at the implications of this work for those concerned with diagram design. The nature of diagrams is dealt with first.

Consider the proposition that, very broadly speaking, pictorial illustrations display mainly physical appearance, diagrams exhibit relationships, and symbols merely assert existence or act as indicators.

When the work described in this dissertation commenced it soon became apparent that clear-cut categories between diagrams and non-diagrams were impossible to maintain. One often meets hybrid forms which apparently function in part as illustrations, in part as diagrams, and in part as symbols.

However, the objectives of this work were to:

1. Propose a terminology for discussing diagrams.
2. Provide a structural scheme for analysing diagrams.
3. Identify the fundamental modes of graphic organization found in diagrams.

This required the examination of many specimens from diverse application areas and the detailed analysis of selected specimens. Given the hybrid nature of many graphic displays, which may in part perform diagrammatic functions, the net for collecting specimens for analysis was cast wide. It follows that the method of selecting specimens for examination, the process of analysis, and its attendant terminology needed to be capable of the most general application.

The terminology proposed in this work is in part based
upon a grammatical analysis of the spatiality defined by what I have called the content models of diagrams. I would suggest that it can be seen from the analyses described that this approach has the merit of being applicable to both highly figurative illustrations, or highly schematized diagrams. For the purposes of this study diagrams are not necessarily viewed as a distinct species. It is perhaps rather more appropriate to speak of diagrammatic tendencies in graphic displays, and thus diagramming becomes, as it were, a form of picture-making for a particular class of exposition.

It follows from this that I am unable to accept the notion one may initially hold that a diagram is merely some sort of highly schematized representation. If one accepts this concept, a diagram would be simply a graphic display occupying the middle span on a continuum such as the 'scales of iconicity' proposed by Moles (1968 pp24-26). This continuum would range from realistic pictures at one end to graphically economic symbols at the other [1].

I have argued that the only tenable determinant for establishing the diagrammatic nature of a graphic display is its function; that is, its use in displaying relations. Its graphical qualities, such as say being composed only of straight lines, are in a sense incidental. A high level of schematization may serve to emphasize what is relevant but it is not an essential quality. For example, a highly figurative depiction of a tree may be used to diagram some set of family relations.

What makes a diagram a diagram is the ability of users to recognise in it relations applicable to what it is the diagram represents.

The relational meaning of a diagram is taken from the arrangement of its elements, and in this respect it is akin to a sentence or text. Although we can distinguish between sentences and diagrams, in that amongst other things the former have a one-dimensional, one-directional scheme to
order their elements, and the latter have the potential to utilize fully two (or even three) dimensions, both make use of a grammar to establish their meaning.

By varying the structure of a sentence, but retaining the same words, we may alter its meaning. In the same way we can change the meaning of a diagram by varying the way its elements are structured. Although strongly governed by invented conventions, I have also argued that this grammar of diagrams has its origins in our experience of the world.

It may be that in some way diagrams can offer evidence of a link between spatial intuition and language competence. Such possibilities have been noted by others (cf Hardin 1981 p8). Whether this ever proves to be the case or not, it does seem that graphic displays are susceptible to the grammatically-based analysis offered as part of the thesis presented here. Basically this analysis allows for a distinction to be made between the various, apparently discontinuous, spaces which are sometimes depicted in graphic displays.

These spaces may be regarded as fulfilling either noun or verb-like functions. Elements occupying noun spaces function like nouns and elements occupying verb spaces function like verbs. These elements relate to what it is they represent by means of the mode of correspondence, which can be more or less literal. They can be depicted in a more or less figurative manner. If a graphic display shows a single homogeneous space depicted in a highly figurative manner, we have what is normally called a realistic illustration. In this case the noun and verb spaces can be said to be coextensive. The more that discontinuous noun and verb spaces seem to be detectable, the more likely we are to have a graphic display the function of which is diagrammatic.

A diagrammatic function is also more likely, although not inevitable, the less literal the mode of correspondence, and the less figurative the mode of depiction.
The diagrammatic tendencies of graphic displays may be summarized as shown in Figure 10-1, which exhibits a three-way classification in terms of:

- Literal/Non-literal (mode of correspondence)
- Figurative/Non-figurative (mode of depiction)
- Continuous/Discontinuous (noun and verb spaces)

Each cube represents a location with three classifying co-ordinates. Locations at the intersection of the Literal and Discontinuous co-ordinates have been omitted as these are logically inconsistent. This gives five possible locations. The arrowed cube is defined by the Literal, Figurative, and Continuous co-ordinates, and this location would be occupied by any graphic display we might be disposed to call a pictorial illustration. We should not think of the six categories as discrete, but rather we should envisage them as merging one into the next. Neither should we regard it as necessary for a display to occupy a single location. Its various elements could be, as it were, distributed throughout the model in varying degrees. As we move away from the arrowed cube, the more we are likely to encounter design characteristics appropriate to the representation of relations, and hence the more we enter the territory of the diagrammatic.

This blurring of borderlines and its tendency to unite diagrams with all pictorial displays had one particular consequence for the thesis contained in this dissertation. It became necessary to qualify the third aim of identifying the fundamental modes of organization found in diagrams. This aim is now restricted to those elements and spaces of content models which are essentially non-literal in their mode of correspondence and non-figurative in their mode of depiction. Graphic displays using largely these modes are those which are most unequivocally diagrammatic in function. With this modification the aims of the project have been achieved.

Candidates for the modes of organization have been proposed. These nominations, and their relation to the
modes of correspondence and depiction, will be discussed next.

Figure 10-1

Modes of depiction

Figurative

Non-figurative

Noun and Verb space

Discontinuous

Continuous

Modes of correspondence

Literal

Non-literal
A major portion of this dissertation has been devoted to a description of the interpretive modes of correspondence and depiction which I have proposed as being the major variables available to the diagram maker. These modes, it has been argued, are related to the fundamental modes of graphic organization which are available for the exposition of relations. In particular, the less literal the mode of correspondence and the less figurative the mode of depiction used in a graphic display, the more likely it is that one or more of the modes of graphic organization will be strongly evident.

It has been proposed in this dissertation that the three modes fall under the major categories nominated by Morris (1938) for the study of signs of all sorts; these are the categories of pragmatics, semantics, and syntactics.

Pragmatics is concerned with signs and their users, and in particular with the interpretation users place on signs. With regard to pragmatics in the case of diagrams, I have used the term mode of correspondence to designate the relation between the content model of a diagram and what it is the diagram is taken to represent. This relation is envisaged as a continuum. It ranges from what I have called a literal correspondence, as in the case of a street map, to a non-literal correspondence, as in the case of a flow chart representing the logical structure of a computer program.

The notion of there being a literal correspondence between some image and what it is said to picture is known in semiotics as iconism, and the issues surrounding this are hotly debated. The example I have just cited, of there being some sort of similarity between a street map and the streets to which it refers, would be, I suspect, sufficient for most people who have not considered the notion deeply, to accept unquestioningly the concept envisaged. However,
this notion has been challenged and in this dissertation it has therefore been necessary for the chapter on the modes of correspondence to be preceded by a somewhat lengthy discussion of these issues. These arguments centre on the question as to whether there can be said to be such things as realistic pictures which naturally resemble the things they represent, or whether all pictures use entirely conventionally coded systems of representation.

The position taken for the work described here can be summarized as follows. Whilst it can be argued that convention plays some role in most pictures, there is a very useful sense in which some graphic displays may be said to correspond literally, to some extent, to the things they represent. This is particularly so in the case of pictures which make use of systems of projection, such as geometric perspective, the most notable example being colour photography. The correspondence between picture and pictured however can be a matter of degree, and we may suppose that the less literal this correspondence, the greater the role of convention in correlating the two. Undoubtedly cultural issues come into play quite strongly when we represent, say, family relations by using a depiction we may otherwise take to be a tree. I have therefore emphasized that a distinction must be made between the object depicted by a diagram, or as I have termed it, the content model, and what it is the diagram is taken to mean.

Semantics is concerned with the relation between signs and their objects. In the case of diagrams this is the relation between the diagram itself and the content model. Here the mode of depiction comes into play. Again this is to be thought of as a continuum, this time concerned with the degree of fidelity with which the image is rendered, that is, the extent to which it is barren of detail. In this respect the mode of depiction has parallels with Moles (op cit) 'Scales of iconicity' previously mentioned.

The mode of depiction can range from the figurative to the
non-figurative. The process of moving from the figurative to the non-figurative has been described in this dissertation as schematization. At the extremes of schematization, the characteristics depicted in a diagram will be of the most generalizable nature and therefore we are probably unlikely to recognize what is represented without the aid of captions, context or conventions. This is certain to be the case where the mode of correspondence is also non-literal.

Syntactics is concerned with the relations between signs. With regard to diagrams these relations are governed by the modes of organization. These are the perceived characteristics of diagrams onto which users map the relations represented. Graphic displays which can be used diagrammatically may have additional visual characteristics, besides the modes of organization, which are also important in influencing our reactions to them. Some of these additional characteristics, which are chiefly evident in figurative displays, have been considered in the work of others mentioned in this dissertation (cf Ashwin 1979; Goldsmith 1978, 1980, 1981).

The main purpose of this present study has been to isolate the fundamental modes of graphic organization of diagrams. From the review of the graphic displays considered during the course of this work, and the detailed audit of the selected specimens reported in Chapter 9 and Appendix B, it has emerged that these modes of organization are quite restricted. In discussing what are taken to be similar ideas, others have noted this restriction. Fitter and Green (1979 p239) for example tell us that,

'Perceptual codes are severely limited in vocabulary size...'

Three candidates for the modes of organization have been proposed as part of the thesis presented here and these are used in diagrams to represent the general concepts of association, sequence, and value. I have cited Venn diagrams, flow charts, and bar graphs, respectively,
as graphic displays in which these modes of organization are strongly evident.

It is perhaps a consequence of the influence of the modes of organisation, and the frequent predominance of one or other in groups of displays, that has led some of the few commentators on diagrams to propose families of diagram types. Notable here are Karsten (1925 p7vi) and Macdonald-Ross (1977a p70) whose proposals have been mentioned in Chapter 2. Whilst such classifications may be useful for other purposes, I am uncertain of the value of these schemes to designers of diagrams. In working with a taxonomy of diagram types there may be a tendency to design within common families and to overlook the possibilities of hybrid forms.

Following a lead given by Macdonald-Ross (ibid), I propose that a more productive approach to diagramming for any given case may be to select from the various available structural possibilities which come to mind when considering the 'interpretive rules [a diagram can] embody'. I would assert that at a fundamental level these rules of interpretation arise from the modes of organization. Such an approach to diagram design will be given in more detail in Section 10.4 of this chapter.

It would seem that the modes of organization become more evident the less literal and the less figurative are the modes of correspondence and depiction. Nevertheless their presence can be identified in many diagrams which tend towards the literal and the figurative. It is perhaps appropriate at this point to discuss the value of figurative depiction in diagrams, especially as it relates to non-literal modes of correspondence.
10.3 Value of the figurative and non-literal modes

It would seem from the specimens reviewed for this work that diagrams are very pliable, having the potential to embody a variety of modes of correspondence and depiction in a single display. This characteristic makes them extremely powerful devices for communication and, as I have pointed out, well able to unintentionally mislead. This has been discussed in the chapter on 'Metaphor in diagrams'. It has been argued that this potential to mislead is greater when the mode of correspondence tends away from the literal, and particularly when the mode of depiction is also highly figurative. The reader of a diagram may be persuaded by a figurative depiction that what is seen literally corresponds to what is represented, instead of seeing the content model as a visual metaphor. It is probable that diagrams which use a non-literal mode of correspondence are more likely to mislead when what is represented exists in a physical form. In this case, if the reader is merely aware that the referent is a physical object but is uncertain of its appearance (as might be the case with some of our internal organs, say), it is quite possible that a literal mode of correspondence may be assumed. Such an assumption may be encouraged when a highly figurative mode of depiction is employed. This of course would also depend on the extent to which the reader is familiar with the metaphoric vehicle employed in the content model of the diagram. Take the example of our nervous system. We may well be unfamiliar with its visual appearance, but, its depiction as a telephone exchange system may not mislead us because of our familiarity with equipment of this sort. One might also expect that confusions are less likely in the case of intangible referents, where one is perhaps less likely to believe that the content model of a diagram has any physical correspondence to what it stands for. However, even in these two cases, there is still the possibility that some characteristics of the content model may be inappropriately transferred to the referent.
Notwithstanding this, the combination of the non-literal and the figurative modes can be of immense value for the purposes of implying indirectly what cannot be otherwise expressed graphically. A number of diagrams which make use of this have been included as examples in the chapter on 'Metaphor in diagrams'. Consider also Figure 10-2 in this present chapter. The modes of organization which enable us to read this diagram of an economic system are chiefly concerned with linking and variation. The linking elements tell us the sequence in which the various reservoirs are connected. The variation in the size of pipes and reservoirs may be taken to be significant and to relate to differences of some values. Also, as with all diagrams, grouping is in operation, enabling us to allot the various elements to their appropriate classes. Additionally, our understanding of this diagram may be assisted by its fairly figurative depiction as some sort of plumbing system. We see what is represented in terms of flowing, filling-up, and emptying, which are ideas we associate with water in pipes and tanks. These ideas cannot be expressed as directly in graphic terms as can the modes of organization. So, in order to understand the diagram, we must recognise the mode of depiction as that which is appropriate to a plumbing system as well as understanding the appropriate characteristics of such a system and then transferring them metaphorically to what is represented. It follows that we must know a priori which characteristics are appropriate. We may be aware of many attributes which plumbing systems and flowing water possess, but only a few of these will be applicable to the circulation of money. One is almost forced to the conclusion that in the case of non-literal, figurative diagrams there is a sense in which one must understand what the diagrams mean before one can read them!

Culture and convention must play a large role when the visual metaphor used for diagrams is highly particular in its character. A certain amount of pre-knowledge of what is referred to by such diagrams would seem to be required.
THE ROUND FLOW OF MONEY INCOME AND EXPENDITURE

10/12
Segal (1981) has pointed out that diagrams can whisper their message or shout it in a loud voice. This has much to do with qualities of the image, such as whether the lines used are hesitant or bold in their appearance. These characteristics can be regarded as determining the diagram's 'tone of voice', to use Segal's (ibid) phraseology. Diagrams can also tell their story disapprovingly, neutrally or joyfully. Variations in the degree of schematization and, in the case of highly figurative displays, the nature of the metaphoric vehicle used, are probably largely responsible for this variable, together with the characteristics of the graphic marks used. These characteristics are part of what Ashwin (op cit) calls gamut, which has been mentioned in section 7.2 of Chapter 7.

Viewed in this way the figurative mode of depiction would seem to perform an adverbial or adjectival function on the modes of organization, qualifying their meaning. If in a diagram two elements are linked by what we take to look like a railway, we are likely to infer more about the connection represented than if a simple, characterless line is used. In their least figurative mode, the modes of organization produce what Stewart (1976 p137) has called an 'armature diagram' (see Chapter 7). Here I am using armature in a similar sense to the way sculptors use it; that is, to refer to the wire framework used to support the clay when modelling, say, figures.

Making a diagram more figurative is the equivalent of adding more clay and doing more modelling. If we start with a display which uses a figurative mode of depiction, then peeling away the clay, or schematizing the display, will tend to reveal the armature, or underlying diagram. It follows that the more clay and modelling used, that is to say the more figurative the mode of depiction, the less evident any mode of organization is likely to be. Also, the less literal the mode of correspondence, the less particular a diagram's character is likely to be and the greater the potential for generalizability of its modes of organization.
Hence the emphasis in this work on the non-literal and the non-figurative, whilst acknowledging that hard and fast demarcations are impossible to maintain.

It should be said that even with schematized armature diagrams, more can be inferred than the basic notions of association, sequence and value, which are expressed by the fundamental modes of organization of grouping, sequence and value. For example, in Figure 10-3 the curved flowlines are somehow more appropriate than if they had been angular, although both styles would express linking. The curves suggest a 'pouring-in', curves being a characteristic of flowing substances tipped from one vessel to another. Even here there is a vestige of the figurative mode and I would again argue that metaphor is in operation. At the most fundamental level there is the linking between elements. This however is qualified by the curve of the lines and the fact that A and B are above C. These combined lead us to attach the generalized notion of flowing. This inference is encouraged by the use of the arrow convention which establishes direction. Direction having been established I would argue that our experience of the natural movement of substances transfers to the content of the diagram and informs us of the character of the linking.

I would suggest that when we judge one arrangement of elements in a diagram to be more appropriate than another, it is because of the association of such arrangements with some subtle abstract quality or phenomena encountered in the real world. This quality will be applicable in some way to the referent of the diagram. However we may not be very aware of this real world connection when we make such judgements. When we make diagrams such considerations seem to be subconscious and are often characterized as intuitive. Even the 'tone of voice' referred to earlier, as characterized by bold versus hesitant lines, probably owes much to our previous experience of the conditions under which marks of these various sorts are made.

In the light of the aforesaid, we are now in a position to
review the concept of a diagram and to consider the implications of this for the designer of diagrams and the teacher of diagram design.
10.4 Implications for diagram designers

As viewed in terms of the thesis presented here, the concept of relations would seem to be the key to arriving at a working definition of the term 'diagram'. It is only this concept which is useful for separating what we may call diagrams from other graphic displays. The relations we recognise in diagrams may be used to stand for the relations the diagram represents. What makes a diagram a diagram is, therefore, the way it is used and is nothing to do with, say, the nature of its rendering. Thus diagrams may vary in their modes of depiction, which can range from the figurative to the non-figurative. Looked at in this way a diagram is not merely a highly schematized picture, although schematization, which results in a non-figurative mode of depiction, can emphasize the modes of organization which seem to be fundamental to the exposition of relations. In certain important classes of diagram, these modes of organization are restricted to those capable of being used to express the general concepts of grouping, linking and variation. A figurative mode of depiction can be used in an adverbial or adjectival way to qualify the modes of organization.

The relations exhibited in a diagram may correspond to the relations they represent in a literal or non-literal way. However, one may object that only displays with a non-literal mode of correspondence can be properly called diagrams (cf Maldonado 1961). The separation of diagrams from non-diagrams on this basis seems untenable, given that in some cases a distinction between the literal and non-literal is difficult to maintain. In the case of non-literal diagrams it is as if we take the content model depicted in the diagram to operate as a kind of visual metaphor for what is represented. But, where relations within a display are governed by convention to a very high degree, as in the case of algebraic formulae, it seems inappropriate to regard such relations as diagrammatic.
I offer the following definition:
'A diagram is primarily a graphic display which depicts spatial relations. The spatial relations depicted in a diagram may represent other spatial relations in some literal way, or they may represent non-spatial relations by means of graphic metaphor.

For the purposes of the observations which follow I regard the design of a diagram as being a process which includes the structuring of the content model. Here the designer is not merely a prettifier of someone else's layout or a straightener-up of lines. This operation, as Garland (1979 p22) has pointed out, often adds nothing and can sometimes emasculate a diagram. Such emasculation may often be a consequence of removing subtle abstract qualities of the sort described towards the end of Section 10.3. I shall regard the diagram designer as a 'transformer', in the sense that this term has been used in relation to Isotype design (Kinross 1981). That is, as a 'skilled professional communicator who mediates between the expert and the reader' (Macdonald-Ross and Waller 1976). Put simply, the diagram maker turns what is, usually, essentially non-visual material into diagrams, with the purpose of making that material readily assimilable by the intended reader.

I shall now discuss how this particular way of regarding diagrams, and the identification of the modes of organization, can be of value both to the designer of diagrams, and to the teacher of diagram design.

The analysis described as part of the thesis presented here provides a terminology for dealing with diagrams. Naming a concept enables one to recognise it as a component of the whole structure of which it is part and allows one to pay attention to it and deal with it. I judge the provision of this terminology to be of potential value to the subject of diagrammatics.

I have proposed the terms, mode of correspondence,
mode of depiction, and mode of organization and these are of particular importance. They express, in what I regard as fairly accessible terms, important concepts concerned with the less accessible ideas of pragmatics, semantics and syntactics. The separation of these components of diagrams is important when considering the likely effectiveness of graphic displays. We shall look at each in turn.

First let us consider the mode of correspondence and in particular the non-literary case. Even if we can assume that readers of a graphic display will correctly identify its content model, unless we can also assume a common cultural background and education we cannot be certain that the appropriate attributes will be transferred from the content model to the referent. In truth we can never be absolutely certain of this without somehow actually testing readers' responses. Nevertheless, being aware of the existence of this pragmatic level of interpretation could alert the diagram maker to potential difficulties.

The mode of depiction can play an important role in establishing the mode of correspondence. The more figurative the mode of depiction, the more particular the attributes of the content model may appear to be. The gratuitous use of the figurative mode, as say for the purposes of decoration, may imply inappropriate attributes. However its use as an adverbial or adjectival qualifier of the content model may be of great value. A usefully circumspect approach to diagram design should result if the diagram maker has an appreciation of:

1. The figurative mode of depiction both as a particularizer or as a metaphoric qualifier of the content model.

2. The potential danger of readers mistaking either of these possibilities for the other.

Finally there are the modes of organization. The principal finding of this study is that in non-literary,
non-figurative diagrams the fundamental modes of graphic organization are those of grouping, linking and variation. These can be used to represent concepts concerned with association, sequence, and value. Characteristic applications are diagrams which show classifications, processes, and rankings respectively. This has been laid out as a table in Figure 8-6. There are many important variables that a diagram designer needs to deal with when using the literal mode, which include such things as viewpoint, degree and nature of schematization, etc. However, as already indicated, the non-literal mode is of primary interest here. How can the taxonomy of organizational modes help in the design of diagrams which are essentially non-literal? Earlier in this chapter I rejected the notion of working with a taxonomy of diagram types, which could be potentially restricting, in favour of an approach based on the interpretive rules of diagrams. I have asserted that, at the syntactic level, the interpretive rules of diagrams arise from the modes of organization, which in turn take their meaning from the way we interpret the visual world generally. So one means of generating a series of alternative content models for an essentially non-literal diagram could be to use the modes of organization as a check list of what may be regarded as conceptual building bricks. Actually, rather than the modes of organization, it is the diagrammatic interpretations one places upon them which may be most useful. Given some non-graphic content for a diagram, the diagram maker should ask:

1. What are the issues of association?

2. What are the issues of sequence?

3. What are the issues of value?

Having identified any issues of association, sequence or value, it follows that when selecting and developing the content model, care should be taken to emphasize, or model, only those issues which are judged to be relevant.
For example, when diagramming the performance of motor vehicles in different price ranges in terms of fuel consumption, one may choose to picture the various distances travelled on one gallon of petrol rather than, say, the height of the piles of money it would take to buy a car from each group.

Having identified the relevant issues, the various graphical forms of grouping, linking, and variation can then be matched against these. By following this process it is possible to generate various armature diagrams. This perhaps requires a taxonomy of applicable graphic forms, and the basis for such a taxonomy has been given in Figure 8-7. This may be capable of extension.

Now, it has already been pointed out that distinctions between the literal and non-literal are sometimes hard to maintain. During the process of generating armature diagrams, consideration should be given to exploiting any kind of similarity which could exist between the content model and what it is the content model is intended to represent. For example, there is a sense in which the sequence of captions in Figure 10-4 seems appropriate in a way which another sequence would not. One should be alert to the possibility that even non-figurative diagrams may remind a reader of something. The designer should be on the look-out for any possible resemblance a content model may have to anything. Any resemblance should be taken into account, and a judgement made as to whether it is likely to enhance, or interfere with the meaning of the diagram.

The more figurative the mode of depiction is, the more particular the content model of a diagram will appear to be. In this case, the question of the appropriateness of the metaphoric vehicle is even more pressing.

The possible qualification of the armature diagrams, with a figurative mode of depiction, and the adoption of an appropriate tone of voice, should be carefully considered. Also, care should be taken not to camouflage the message;
this is more likely to happen when a highly figurative mode of depiction is used.

It should be stressed that the process described above is not offered as a complete and systematic approach to diagram design but is proposed as a means of generating various graphic structures from which a selection can be made for development.

Neither is it proposed that the method of analysing diagrams into significant elements, described in Chapter 3 and applied in Chapter 9, should be used for the purposes of designing diagrams or teaching diagram design. The practical application of this latter method of analysis outside research applications is probably limited; however, it does give rise to a terminology with which practitioners may discuss diagrams.
This present work has been of necessity largely speculative and theoretical in character. This is because of the newness of diagrammatics as an area of serious investigation and the consequent lack of tried and tested methods for dealing with it. However, it should be said that some borrowings from semiotics have been possible. Much of the work has been concerned with devising a theoretical framework for the study of diagrams and, whilst this was based on an examination of many specimens, it also relied heavily on the author's experience as a designer of diagrams and a teacher of diagram design. In many ways what has been reported here can be seen as a ground-clearing exercise. It follows that I should now give some indications for possible avenues of research which may arise from this work.

Whilst this work has been essentially theoretical it is nevertheless hoped that in part, at least, the outcome might be of practical value to practitioners and teachers. One useful avenue of further inquiry would be to develop, and to test the usefulness of the method described in Section 10.4 for generating various content models. One would also like to know if the graphical characteristics used for expressing the modes of organization as displayed in Figure 8-7 represent an exhaustive list, and this might be the object of another survey. Which of these are most readily perceived as representing the fundamental modes of organization is another question which could be tested. The taxonomic model relating modes of correspondence, depiction, and organization proposed in this work (see Figure 9-2) might also be useful for any survey aimed at establishing the incidence of various diagrammatic characteristics used for exposition in different subjects. Knowlton (1966 p180) makes a similar proposal for his own scheme, and to paraphrase him using my terminology, one might expect to find more literal diagrams used in biology and more non-literal ones used in the formal sciences.
It would also be interesting to know whether there is a bias towards any particular mode of organization in the non-literal diagrams used in different subjects. I suspect that the greater the claim a subject has to be scientific, the more likely we are to find a high proportion of diagrams concerned with value. The simple line graph representing a range of values immediately comes to mind here. One might also expect to find the figurative mode of depiction to be more in evidence in popular works than it is in those aimed at the specialist reader.

In addition to these possibilities this present work raises questions which are less susceptible to formal testing. Take for instance the modes of organization found in the diagrams surveyed. One would like to know to what extent the presence of these modes is a consequence of the cultural environment in which the diagrams were produced and read, and to what extent it is a question of the innate disposition of the producers and readers. If the former is the most important factor then the modes of organization have relevance only to modern Western European cultures. If, on the other hand, our tendency to perceive the visual characteristics of diagrams along the lines described arises from our propensity to construe the world in particular preset ways, we can expect that highly schematized diagrams will have the same meaning, at the most fundamental level, for all people at all times. The German philosopher Kant (Scruton 1982), for instance, believed that the mind has a prior system of categories which structure our experience of the world, bringing an organization to the otherwise disorderly data of our senses. From this point of view our understanding of the world is to some extent determined by our genetic endowment. This is in direct opposition to the empirical philosophers such as John Locke (Berlin 1956 pp30-112) who believed the mind is like an empty box which is filled with experience. From this experience a structure gradually emerges. In this case our understanding of the world is derived directly from experience alone. A recent exponent of the idea of innate endowment is Chomsky (Magee 1982 p173-183)
who proposes that we come into the world with what amounts to a biologically determined propensity to learn human language. To what extent we are pre-programmed to recognize the modes of diagrammatic organization would be difficult to determine experimentally. Cross-cultural studies on picture perception might yield some clues, as might future discoveries in the field of neural research. With regard to the modes of organization as possible candidates for representing some aspects of our innate scheme for organizing our sensory data, it is interesting to note proposals made in the field of artificial intelligence for the processing of visual information. I assume that those working in this field believe that developing efficient schemes for machines offers a model for the way humans operate. One proposal made by Marr (1979), for example, suggests that at some fundamental level of processing visual information to identify objects, there should be a mechanism for determining the 'natural axes' of objects. A collection of these axes can be represented by pipe-cleaner figures. Figure 10-5 shows that the representation of an object does not have to reproduce the shape of its surface in order to describe it adequately for recognition. These natural axes form part of a more complete description and locate 'volumetric shape primitives of a variety of sizes'. See Figure 10-6.

This would seem to parallel the linking and variation modes of organization proposed in this dissertation. We have, then, armature structures defining a figure's topology, to which bulk is added. As pointed out earlier, the process of schematization in diagrams can lead to the emphasis of the sequence of connections and the value or size of parts, in addition to the simple association of elements.

In artificial intelligence the suggestion is that as machines have a finite 'memory' and presumably so do humans, it is very inefficient to have brain cells dedicated to recognizing, say, cats, bicycles or fat men. Anyway, such a scheme would require a given object to be perceived in the attitude in which its archetype is stored
Figure 10-5
From: Marr (1979 p59)

Figure 10-6
From: Marr (1979 p55)
So separate recognition schemes would be required for identifying a fat man standing as seen from above, a fat man sitting as seen from the side, etc. It is argued that what is needed is a more generalizable process by which our fat man is recognisable, even if he strikes a unique pose. Also, parts of the pattern of recognition which enable us to identify a fat man would be the same, at some intermediate level of generalizability, as those which enable us to identify a fat orang utan. Otherwise what else would it mean to say that the two are similar?

Whether mechanisms of the sort Marr describes exist, and whether we are, as it were, pre-programmed to organize visual information using them, is at the moment a matter of speculation. However the similarity between the scheme of analysis described by Marr and the modes of organization identified in this dissertation is worthy of note. It would perhaps support any notion that the modes of organization may be important at some fundamental level in the way we ascribe meaning to what we see. In connection with this notion, the ideas of Daley (1982) are of interest. She (op cit p137) proposes that the activity of design is a,

'systematization of our experience of the physical world. The ways in which we symbolize and represent that kind of systematization may be the most important clues to how we make sense of the world.'

One important means of representing 'that kind of systematization' is the diagram.
Summary

The original objectives of the project were restated and the nature of diagrams was outlined. A modification to one of the original aims was described.

The relations between the modes of correspondence, depiction, and organization were summarized and the somewhat special case of the relation between the figurative and non-literal modes was discussed.

The implications of the findings of this investigation, for diagram designers and teachers of diagram design, were outlined. In particular a process for the generation of alternative content models for diagrams was proposed. This process uses the modes of organization as a basis.

Some suggestions for future research were given and parallels between the thesis reported here and some work done in artificial intelligence were pointed out.
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Appendix A  DIAGRAM SOURCES

A.1 Books

A.2 Periodicals
A.1 Books

Listed below are some of the sources from which I selected the sample of diagrams used as the basis for the investigation reported in this dissertation. Where only the author's name and the date of the work are given, a more complete reference may be found in the Bibliography.

Automobile Association 1973
Book of the British countryside
London: Drive Publications

Blunt W 1955
The art of botanical illustration
London: Collins

Booth (1890)

Brewster and Griscom (1833)

Brinton (1914)

Bronowski (1973)

Brown R nd
Science for all Vol 1-5
London: Cassell

Funkhouser (1937)

George (1964)

Hayter C 1834
An introduction to perspective, practical geometry, and painting
London: Samuel Bagster

Hening (1977)
Herdeg (1974)

Koestler (1967)

Lockwood (1969)

Malton T (1776)

Milner T nd

The gallery of nature
London: W & R Chambers

Mitchell J (ed) 1976

The joy of knowledge library (series)
including the following titles:
Science and the universe
Man and society
History and culture 1
History and culture 2
London: Mitchell Beazley

Miyano Machinery nd

An outline of Miyano
(sales brochure)

Neurath (1936)

Odhams Press nd

The universal home doctor
London: Odhams Press

Partington (1933)

Richards C J 1977

CACTI-MK-1 users guide
Coventry: Lanchester Polytechnic,
Department of Graphic Design
Ruddock E H 1931

*Vitalogy*

Chicago: Vitalogy Association

Staveley Machine Tools nd

(Catalogue)

Tissandier G nd

*Popular scientific recreations*

London: Ward Lock & Co
A.2 Periodicals

Some issues of the following periodic publications also provided the source for some of the diagrams in the sample.

Design

Designer

NATFHE Journal

Observer

Radio Times

Sunday Times

Sunday Times Magazine

The Geographical Magazine

TV Times
Appendix B

ADDITIONAL DIAGRAM AUDITS

B.1 Sensory homunculus

B.2 Diagram of lines (January 1953)

B.3 Universal affirmative proposition

B.4 Computer program flow chart

B.5 ISOTYPE chart on working hours in Sweden
Sensory homunculus

This diagram, shown here as Figure B-1, is from one of a series of French books on physiology, aimed at the popular market. The diagram shows that each part of the body is linked with a particular area of the brain cortex. The brain areas are in proportion to the complexity of possible movement, and the fineness of the sensations which the nerves can pick up, and not the size of the respective body parts. To illustrate this in the diagram, the various parts of the body are depicted either relatively increased or decreased in size in proportion to the associated area of the brain cortex. A certain degree of sophistication in the reader is required if this idea is to be properly grasped. A young child, for instance, might well think that the diagram shows a funny man with big hands. No doubt, the misunderstanding of a Sunday Times reader, evident from the letter shown in Figure B-2, is deliberate.

The various body parts are linked to respective areas of a disembodied brain by a rectilinear network of black lines. This appears to be a kind of cross-reference to a wiring diagram, and, because of the long stretches of parallel lines with right-angled bends, is just as difficult to follow. (This is exacerbated by the fact that the box rule separating the brain from the rest of the diagram is indistinguishable, in terms of line quality, from the linking lines.) The metaphor of nerves as telephone wires is frequently used to explain the functioning of the nervous system, and so it is not surprising to find the graphic conventions of electrical diagrams applied in this manner.

The brain appears to be shown as a transverse cross section of one of its halves, turned on its side. This makes it difficult to relate the brain to the manikin.

It is interesting to compare Figure B-1 with Figure B-3, which shows the connection between brain areas and body.
parts with a colour code. Here both halves of the brain are shown, although much enlarged, and these appear in the same orientation as the manikin. This makes clearer the relation between opposing halves of the brain and body. That is, that the right half of the brain controls the left half of the body, and vice versa.

In the following analysis of the diagram shown in Figure B-1 it was decided to treat the human figure as a single significant element, although it could have been analysed into its various constituent parts, eg, hands, feet, tongue, etc. The simpler approach was adopted as this was judged not to detract from the validity of the audit process. The significant elements are as follows:-

A  Human figure  
B  Sectioned brain  
C  Cortex areas (black line segments)  
D  Double-headed arrows  
E  Single-headed solid arrows  
F  Single-headed dashed arrows  
G  Wavy black lines with dots  
H  Small ellipse  
I  Rectilinear linking lines  
J  Box rule  
K  Fig leaf  
L  Background  

A  Human figure  

The sensory homunculus represents Mr Everyman; however, for the purpose of this analysis we will assume that he represents someone. In that case the mode of correspondence is semi-literal, the various proportions of the body having been somewhat distorted. At the same time the manikin also represents, by its distorted shape, the relative areas of the brain cortex given over to various functions. Here area is mapped into area and, presumably, there is no correspondence in terms of shape. This also gives us a classification of semi-literal. This then is
one of those interesting cases where a significant element simultaneously represents two separate, if related, objects.

The mode of depiction is essentially **figurative**.

**Intrinsic features**

A1 The spatial relations exhibited in the manikin correspond topologically with those of the average male human we suppose the figure represents. In this sense the figure shows which bits are connected to which bits, and this part of the display is therefore a weak form of **linking diagram**.

A2 The variation in size of the various body parts is an important relational feature in this diagram. Interestingly the variation is not measured between various elements of the same type, but rather against some mental model of what the proportions of a normal person should be.

A3 There is perhaps the tendency to group together the pairs of corresponding features, eg, left hand and right hand, left foot and right foot, etc.

**Extrinsic features.**

There do not appear to be any extrinsic features.

**B Sectioned brain**

This represents the left half of the manikin's brain, and, being sectioned, is **semi-literal** in its mode of correspondence. The mode of depiction is somewhat schematized and may therefore be classed as **semi-figurative**.

**Intrinsic features**

B1 The intrinsic relational features appear to be concerned with the actual geometry of the brain.
Extrinsic features

There do not appear to be any extrinsic relational features.

C Cortex areas (black line segments)

The black, broken line segments represent the various locations of the cortex in a semi-literal manner. The mode of depiction is highly schematized and is therefore classed as non-figurative.

Intrinsic features

C1 The spatial relations describe the general geometry of the brain cortex.

C2 The variation in the length of line segments corresponds to the variation in the area of cortex represented by each segment.

C3 The location of each segment, relative to the other segments and other features of the half brain section, may be supposed to indicate the spatial relations of the various areas of the cortex in an actual brain.

Extrinsic features

C4 The spatial relations describe the location of the brain cortex within the overall geometry of the brain.

D Double-headed arrows

It is presumed that these represent the pathways of neural messages and are therefore semi-literal in their mode of correspondence. The mode of depiction is non-figurative.

Intrinsic features

D1 The arrow convention indicates directional possibilities, suggesting a linking mode of organization.
D2 The shape of these arrows may be presumed to show the geometry of the neural pathways they represent.

Extrinsic features

D3 The linear quality of these elements tends to lead one to group them with all the other lines, which, with the exception of the box rule, have the function of representing the transmission paths of neural messages.

D4 Being located inside the brain half-section tends to group these elements with all the other significant elements inside the half-section.

D5 The location of these elements, relative to the other significant elements and the general distribution of features in the half-section, may be supposed to indicate the spatial relations of some of the actual neural pathways within the brain itself.

E Single-headed solid arrows

What goes for D goes, mutatis mutandis, for E.

F Single-headed dashed arrows

What goes for D goes, mutatis mutandis, for F, with the exception of the intrinsic feature of having a dashed quality. This perhaps suggests a less well defined route or some other qualitative difference.

G Wavy black lines with dots

What goes for D goes, mutatis mutandis, for G, with the exception that there is no directional component in G and that these elements are linked to the small ellipse H.

H Small ellipse

The function of this feature is unclear but it does not
appear to have any important relational function, although it is linked to the elements of G.

I Rectilinear linking lines

These lines represent the connections made by the nervous system between various parts of the body and various areas of the brain cortex. The mode of correspondence is on the extreme edge of the semi-literal territory, but is not quite non-literal as these connections do exist. However they exist inside the body and are not normally visible travelling to a disembodied brain as they do in the diagram. The mode of correspondence is non-figurative.

Intrinsic features

I1 The lines link the various parts of the body to the corresponding areas of the cortex represented by C.

Extrinsic features

I2 The linear quality of these elements groups them with other elements indicating neural pathways.

J Box rule

This non-literal, non-figurative element similarly acts as a separator, marking-off the area of the brain part of the diagram from the rest of the display.

Intrinsic features

None.

Extrinsic features

These are essentially those of grouping.

K Fig Leaf
This has no diagrammatic function.

Background

This has no diagrammatic function.
In view of the importance of Henry Beck's contribution to the design of diagrams for transport networks, as mentioned in Section 2.2 of Chapter 2, it is appropriate that one specimen of his work should be included in the diagram audits described in this dissertation. The London Transport Railways 'Diagram of lines' for January 1953, shown here as Figure B-4, may be analysed into the following significant elements:

A Station markers
B Interchange station markers
C Lines
D River
E District line caption box
F Key
G Logo
H Border
I Credit
J Background

A Station markers

There are two sorts of station marker; single-sided and double-sided. Some double-sided markers show linked pairs where parallel lines have common stations. The other double-sided markers are used for termini stations. Within the class of significant elements used as station markers, these double-sided markers serve a grouping function, indicating two sub-classes of station. However, having taken account of these distinctions, we shall now proceed to deal with all station markers as a common class (excluding the interchange station markers which will be dealt with in the next class of significant elements).

The station markers are literal to the extent that in common with what they represent, station markers do occupy some location within a spatial field. However some special
Figure B-4
From: Diagram of lines
London Transport, January 1953
steps would have to be taken to make their distribution evident, say in an aerial photograph, and the relative locations of the station markers, whilst not entirely arbitrary, are not entirely geometrically similar to those of the actual stations. The mode of correspondence is therefore semi-literal. As a high degree of schematization has been used, the mode of depiction is non-figurative.

Intrinsic features

A1 The colour coding of the station markers redundantly recodes the grouping established by the extrinsic code of being physically attached to a particular line. The colour coding also groups station markers with other elements of the same colour (with an exclusion which will be mentioned later in connection with the Piccadilly Line).

Extrinsic features

A2 Station markers are formed into groups together with certain interchange station markers by being physically attached to particular lines.

A3 Certain station markers are grouped by linking, (already mentioned in connection with the double-sided markers) and some by proximity. Those which group by proximity are the station markers of the Circle Line, and those other markers with which they are common.

A4 There is, to some extent, a kind of correspondence between the spatial relationship shown amongst station markers and the interchange station markers, and the spatial relationship that actually exists between the actual stations represented, which is not entirely arbitrary. There is what might be called a Northness and Southness, and an Eastness and Westness. Certainly those stations which are North of the Thames are shown by station markers above the blue line representing the Thames, and those stations which are South of the Thames are shown by markers below it. There is a topological correspondence if
not a geographically accurate one. Readers undoubtedly understand this spatial relationship which is to do with relations which might be called 'hereness' and 'thereness'.

**B. Interchange station markers**

With regard to the modes of correspondence and depiction, what applies to station markers equally applies to the interchange station markers; that is, they are similarly classed as semi-literal and non-figurative. All but one of the interchange stations are grouped into two's or three's. Breaks in the circumference of the ring-shaped markers are aligned within these groups, and this alignment is perceived as a white linking line. This spatial connection corresponds to some degree with the spatial connection which actually exists between the various platforms of interchange stations and which enables passengers to move between the various platforms of the various lines. This feature reinforces the semi-literal categorization, and being highly schematized in its depiction, also reinforces the non-figurative classification. Although this feature does not appear on the Camden Town marker on the Northern line, and all the other markers form into groups of either two or three, each interchange station marker will be treated as belonging to one class of significant element.

**Intrinsic features**

**B1** What goes for A1 goes *mutatis mutandis*, for B1.

**Extrinsic features**


**B3** Some interchange station markers are grouped with other interchange markers by proximity.

**B4** What goes for A4 goes *mutatis mutandis*, for B4.

**C. Lines**
The lines are literal to the extent that they link the various station markers in the same sequence that the lines they represent link the actual stations. As with the stations, special steps would have to be taken to make the actual lines visible and even if this were done, they would not correspond in a geographically similar way to the lines on the diagram. However the diagrammatic lines and the actual lines are topologically isomorphic. The lines are therefore semi-literal, but close to the literal border. The mode of depiction is non-figurative.

Intrinsic features

C1 The lines establish the sequence between the stations by linking. This sequence is made quite explicit, by the use of radii, where lines converge. For example, on the Central Line, it is quite clear that the sequence of stations is Leytonstone to Wanstead and Leytonstone to Snaresbrook, or the reverse of these two, but not Snaresbrook to Wanstead. This feature would seem to take advantage of our understanding of actual roadway or railway systems for expressing its meaning.

C2 The colour coding forms the lines into groups with a common designation, and associates these groups with other elements of the same colour. This is especially important for the operation of the key. The Piccadilly Line, whilst printed in the same colour as the graphic device used to represent the Thames, and part of the logo, is disassociated from them by their different graphic forms.

Extrinsic features

C3 What goes for the relationship between the station markers, as described in A4, goes, mutatis mutandis, for the relationship between the lines.

D River

In terms of the modes of correspondence and depiction the
graphic device used to indicate the river has the same classification as the lines; that is, semi-literal and non-figurative. Whilst it requires a less contrived situation in order to make, say, an aerial photograph of the actual river, and it could be argued, therefore, that its graphic representation in the diagram is more literal than the lines, the route of the river shown in the diagram deviates markedly from the actual route. Nevertheless the depiction is not entirely arbitrary and there is a degree of resemblance between the graphic device representing the river and the route of the river itself.

Intrinsic features

D1 Like the river it represents, this graphic device has a certain wiggliness which is not without spatial meaning.

Extrinsic features

D2 What goes for the relationship between the station markers, as described in A4, goes, mutatis mutandis for the relationship between the graphic device representing the river and the station markers and lines.

E District Line caption box

This non-literal, non-figurative element is essentially a list of the stations, given in the order they are encountered, when one proceeds along the section of the District Line not included in the diagram. There is a vestige of correspondence in that the list follows the sequence of the actual stations. However this feature is not to be understood as a map of the line and whilst slightly equivocal in its classification I have come down on the side of non-literal. The station names, etc, could each have been treated as separate, significant elements, grouped by proximity and enclosure by the perimeter line. Treating this group as a single element was judged not to change the outcome of the audit.
Intrinsic features

The station names are linked by the sequence in which they appear and this establishes the sequence of the stations they represent.

Extrinsic features

The caption box is linked to the District Line by what may be taken as an extension to the perimeter line of the box. The link is given direction by the radius of the linking line as it converges with the District Line which has an arrow head at its termination.

F Key

This element is non-literal and non-figurative, being the key to the whole diagram and not an indication of the layout of stations or lines.

Intrinsic features

F1 All station markers are grouped by similarity of form, proximity, and alignment.

F2 The two classes of station marker are grouped by vertical alignment and similarity of graphic form.

F3 Station markers for a particular line are grouped by colour and horizontal alignment.

F4 All captions are grouped by similarity of form (being Verbal Graphic Language), proximity, and alignment.

F5 The captions are grouped with the station markers to which they refer by horizontal alignment and the linking of the dotted lines.

Extrinsic features
The various station markers, and the segments of line to which they are attached, are grouped with the lines and station markers to which they refer in the diagram proper by means of sharing a common colour. Hence they are grouped with the captions in the key which are the designations of the lines.

G Logo

This serves no diagrammatic function, but simply acts as an identification device for London Transport.

H Border

This also has no diagrammatic function.

I Credit

Like the border, whilst having other functions, this element is not diagrammatic.

J Background

Whilst having no features itself which might have a diagrammatic function, it could be argued that the background occupies the same semi-literal space of the content model as do the station markers and the lines. The background is, as it were, deneutralised by the foreground elements, and perhaps can be said to have the same modes of interpretation.
This diagram of Euler's is shown here as Figure B-5. We know from Euler's (Brewster and Criscom 1839 p340) commentary, previously quoted in Section 3.4 of Chapter 3, that we are supposed to understand the content model of this diagram as two overlapping spaces (or perhaps we should think of them as disks). Understood thus, A is part of B, rather than say, B surrounding A, or even A and B being two things, one inside the perimeter of hoop B and one inside the perimeter of hoop A. This idea of the space of surrounding elements continuing through, or maybe over or under the enclosed elements, is perhaps made clearer in Cherry's (1978 p224) diagram which uses shading to good effect (see Figure B-6). So, although we may initially identify four significant elements in Figure B-5, two rings and two letters, the letters serve a labelling function for the two disks defined by the rings.

The elements are:

A  Small disk  
B  Large disk  
C  Caption 'A'  
D  Caption 'B'

This diagram refers to an abstract proposition, therefore the mode of correspondence of all its elements is non-literal. No attempt has been made to depict the circles as, say, fields of grass or crowds of people. The mode of depiction is non-figurative.

A  Small disk

Intrinsic features

There are no intrinsic relational features

Extrinsic features
A1. Its circular shape serves a **grouping** function, associating it with the other disk-shaped element.

A2. There is also the **grouping** we perceive in terms of disk 'A' as it were, belonging to disk 'B'. This ownership is not seen as reciprocal.

A3. The **variation** in the size of the disks can be interpreted in terms of rankings.

**B** Large disk

Intrinsic features

There are no intrinsic features.

Extrinsic features

What goes for A, goes, *mutatis mutandis*, for B.

**C** Caption 'A'

This element serves a labelling function for the disk of A.

**D** Caption 'B'

What goes for C, goes, *mutatis mutandis*, for D.
Figure B-7 shows the application of international flow chart standards to a computer program written in the language Basic. The flow chart represents the program to the extent that it pictures the essential sequential structure of the program. The mode of correspondence is therefore non-literal for all significant elements. This highly schematized presentation is also non-figurative for all significant elements.

The diagram may be analysed into the following significant elements:

A. Oval boxes
   Intrinsic features
   None.
   Extrinsic features
   Al. The box-like characteristic groups this element with all the other box-like elements.

B. Chamfered boxes
   What goes for A goes for B, mutatis mutandis.

C. Rectangular boxes
Intrinsic features

None.

Extrinsic features

C1 What goes for Al goes for Cl, *mutatis mutandis.*

C2 The variation in size of the rectangular boxes tends to suggest a ranking, however this is not an appropriate inference.

D Diamond shaped boxes

Intrinsic features

Although not a strictly relational feature, there does seem to be some sort of directional quality about the diamond which, as it were, invites the maker of flow charts to use its vertices as inlets and outlets for the arrows in a way that the other shapes do not.

Extrinsic features

What goes for A goes for B, *mutatis mutandis.*

F Arrows

Intrinsic features

F1 The arrow convention adds a directional component to the linking function of these significant elements.

Extrinsic features

F2 The arrows link the boxes, establishing the sequence of execution for the instructions each box represents.

G Program instructions
These serve a labelling function for the boxes.

H True/false labels

These serve a labelling function for the arrows.
It is appropriate that at least one audit on an ISOTYPE chart should be included in this appendix. The importance of the ISOTYPE system, devised by Otto Neurath (1936), has been mentioned in Section 2.2 of Chapter 2.

The specimen shown in Figure B-8 can be analysed into the following significant elements:

A  Clocks
B  Heading
C  Pictogram of factory
D  Dates
E  Key caption

A  Clocks

The clocks are used to represent time in several senses. They are used in groups to represent simultaneously an average day and a 19 year period. They are also used individually to represent the passage of one hour. In all cases the mode of correspondence is non-literal. Each device depicts a somewhat schematized clock face and is therefore semi-figurative.

Intrinsic features

A1  Each clock reads 'one o'clock' and this reinforces the idea that each unit represents one hour. However this is not strictly a diagrammatic, relational feature.

Extrinsic features

A2  The clocks group themselves into rows by proximity and alignment, each group representing a 19 year period.

A3  The proximity also implies a linking which, together with the left to right reading convention used for these
Sweden.

Working Hours in Manufacturing Trades

Each clock represents one working hour per day.
charts, establishes the sequence of the hours.

A4  The arrangement of the rows also implies a vertical linking. This, together with dates attached by proximity to each row, establishes the top to bottom sequence.

A5  There is also a vertical alignment which groups clocks of a common hour. That is, all first hours form a column, all second hours form a column, etc.

A6  The variation in the length of the rows, and hence in the number of clocks in them represents the variation in the number of hours worked in each day for the period of years for which each row stands.

B  Heading

This simply labels the whole diagram and serves no relational function.

C  Pictogram of factory

This helps to reinforce the context of message and serves no relational function.

D  Dates

They serve a labelling function for the rows.

E  Key caption

Whilst making clear the way in which the chart is to be read, the caption itself has no relational function.
C.1 List of publications

C.2 Reprint from the Information Design Journal
C.1 List of publications

Richards C J 1974
The automatic preparation of three dimensional
drawings from data derived from orthographic views
In: Technical documentation
symposium proceedings
London: Society of Electronic and Radio Technicians

Richards C J 1974
Computer-aided construction of technical
illustration (CACTI)
In: CAD 74
Conference proceedings
Guildford: IPC Science and Technology Press

Richards C J 1975
Computer-aided construction of technical
illustrations
MPhil thesis
Coventry: Lanchester Polytechnic

Johnson R D and Richards C J 1977
Teaching computer drawing to students of art and
design
In: Abbas S A et al (eds)
CAD ED
Conference proceedings
Guildford: IPC Science and Technology Press

Richards C J 1977
CACTI-MK-1 users' guide
Coventry Lanchester Polytechnic
Department of Graphic Design
Richards C J 1978

Computer drawing techniques used in graphic design and related areas of work - some case histories
the text of a talk presented at Computers for Image-making, the British Universities Film Council Annual Conference, Cardiff
Available from Coventry Lanchester Polytechnic Department of Graphic Design

Richards C J 1978

Some uses of computers in technical illustration
Computer Aided Design 8(2) 94-100

Richards C J (ed) 1979

Computer picture book
Coventry Lanchester Polytechnic Department of Graphic Design

Harrison A E and Richards C J 1980

Computer pictures
Journal of the NSAE 7(2) 4-5

Richards C J 1980

Graphic codes for flow charts
Information Design Journal 1(4) 261-70

Richards C J 1982

Perspective history and computer graphics
The Communicator of Scientific and Technical Information 52, 7-10

Richards C J 1983

Microcomputer aid to cut-away and exploded illustration
The Communicator of Scientific and Technical Information 56, 8-17
Richards C J 1983
Technical illustration and film animation
Computer applications in Design II
Conference report
Nottingham: East Midlands Further Education Council
This article is reproduced here as it is concerned with some issues related to the topic of the thesis presented in this dissertation.
Graphic codes for flow charts

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Introduction

Flow charts have been used by computer programmers both as a design aid and as a means of explaining programs to others. Computer programs in common with written text of natural languages are expressed as linear sequences of units. The graphic codes of flowcharting can exhibit these sequences two-dimensionally. See Figures 1 and 2a. Although flowcharting is not restricted to computing we will confine ourselves to this area for which international (ISO 1973) and other standards exist (BS 1973a).

In this paper we propose new graphic codes. Our concern is with the needs of the chart reader, but the method we propose does not require a high degree of drafting skill on the part of the chart maker. Other methods are mentioned, some of which have different priorities.

Where needed the programming language BASIC will be used as an illustration. Figure 1 depicts a segment of instructions in this language which reads a list of numbers in no particular order and then prints them in strict ascending order. The meaning of the individual instructions may be fairly evident even to readers with no knowledge of BASIC, yet it may not be easy to grasp the intent of the program as a whole. The intelligibility of this program will of course vary with the background of the reader and for some, the mathematical flavour of the instructions will set high emotional barriers to

```
10 READ N
20 LET K=1
30 READ A(K)
40 LET K=K+1
50 IF K<N THEN 30
60 LET L=1
70 LET S=10000
80 LET M=0
90 LET K=L
100 IF S<=A(K) THEN 130
110 LET S=A(K)
120 LET M=K
130 LET K=K+1
140 IF K<=N THEN 100
150 IF M>L THEN 190
160 LET X=A(L)
170 LET A(L)=A(M)
180 LET A(M)=X
190 PRINT A(L)
200 LET L=L+1
210 IF L<=N THEN 70
220 PRINT A(N)
230 STOP
```

Figure 1. This is a computer program written in the language BASIC.
Figure 2a. This shows the application of international flow chart standards to a computer program written in the language BASIC.

Figure 2b. If a flow chart is too big for a single sheet connector symbols may be used to show links from page to page.

understanding. The following description attempts to capture the essence of the program in words:

1. A number is read which gives the length of the list to be examined.
2. The list itself is then read.
3. It is scanned from the first item to the last to find the smallest number.
4. This number is brought to the head of the list and printed.
5. The process is repeated starting from the second item of the new list, then again starting from the third item, the fourth and so on.
6. When the list is reduced to two items and the smaller of these is brought to the last but one place, the process is complete.

Various methods of presenting this process diagrammatically will now be compared.

Standard flow charts

Individual computer processes can be divided into two main groups, actions and tests. International standards (ISO 1973) recommend that these are shown as follows:

- A rectangular box with one flow line entering and one flow line leaving denotes a simple action.
- A diamond shape box with one flow line entering and two more flow lines leaving denotes a test. Each exit line corresponds to a particular outcome of the test.

A caption summarizing the action or test is placed inside the box. Figure 2a shows an application of international flow chart standards to the example program of Figure 1. In addition to the simple action box the variants for denoting input from a card reader and output to a line printer will be noted. These are respectively a box with the top left-hand corner sliced off and a box with a wavy bottom line. The standards may include many other symbols for particular functions including starting and finishing, also shown in Figure 2a.

Considerable latitude is allowed to the user who in practice often feels the need for further local
standards. Here we have adopted the principle of overall flow from top to bottom, of taking forward branches to the right and backward branches to the left.

When a flow chart is too big for one sheet international standards allow for connector symbols to indicate links from sheet to sheet. To demonstrate this technique the flow chart in Figure 2a has been divided into the five parts shown in Figure Zb.

A potential disadvantage is evident. Attempting to follow the flow of the program could lead to a tiresome forward and backward scan through several sheets. For programs containing hundreds of instructions a point could be reached where the effort involved in reading the chart is not sufficiently repaid by any extra insight it might give. We strongly discourage the use of this technique of linking separate sheets of a flow chart as the problem can be avoided if a 'structured programming' approach is adopted.

Structured programming

The aim of structured programming is to produce programs which are easy to design, understand, correct and modify. There has been widespread discussion of this topic and some 400 references have been cited by Knuth (1974). In the more radical proposals (Dahl et al 1972, Wirth 1974) a program is conceived as a hierarchy of blocks, each having one of three fundamental structures:

- Sequence of blocks
- Selection of alternative blocks
- Repetition of a block

Starting with a structure which expresses the overall function of the program, each block is analysed into similar subordinate blocks until eventually blocks are reached which express computer acceptable instructions.

The BASIC language possesses an instruction for expressing the repetition of a block and the readability of a program is improved by its appropriate use. Readability is further enhanced by indenting the blocks to be repeated. Repetition within repetition is expressed by nested indentation. Figure 3 shows these principles applied to the example program. The result is probably at least as useful to the experienced programmer as the flow chart of Figure 2a. Indeed Shneiderman et al (1977) have expressed doubts about the usefulness of detailed flow charts in the designing of computer programs. However, we believe that the power of this graphic form should not be lightly thrown away as flow charts are probably most useful as a means of explaining how complex programs work to those not engaged in their design, or as an aid to teaching computer programming.

Standard flowcharting for structured programs

International standards can accommodate structured programs by means of an indexing system which uses what is called a striped symbol.
This is an action box with an additional division containing a code referring to a subordinate sheet. The rest of the box may contain some caption expressing a specific task in global terms. More detail can be found on the subordinate sheet which can itself refer to further sheets. Figure 4 shows these principles applied to the example program. The adoption of a local standard for the repetition of a loop will be noted as none exists in international standards.

For us, these standards have a particular drawback. Fitting captions into boxes can be tricky, especially the diamond shaped variety and this can lead to either the use of cryptic descriptions or the introduction of large boxes which seem to assume an importance disproportionate to their function.

Alternative techniques
Others have raised objections to standard approaches and have proposed alternatives. Garland (1968) has critically surveyed practice in presenting flow analysis in a variety of fields including critical path analysis, work study, telecommunications, fault diagnosis as well as computer programming. Some of his suggestions are listed below:

- Large box symbols containing captions should be replaced by small standard size nodes with captions placed alongside. This way the caption does not govern the size of the symbol.
- The number of distinct symbols should be kept small. Seven has been suggested as an
optimum (Miller 1956). Standard practice is extravagant in symbol type as can be seen from examining flowcharting templates.
- Flow lines should have curved corners and meet tangentially like railway lines.

The Garland symbols for actions and tests are included in Figure 5. The use of small symbols with captions placed alongside has also been advocated by Small (1973). Compared with international standards this approach reduces the prominence of symbols and emphasizes the flow lines.

Proposals by Nassi and Shneiderman (1973) move to the opposite extreme where boxes become all important and flow lines disappear.

Figure 5. Various alternatives to international flow chart standards have been proposed.
altogether. This approach builds restrictions into the graphic code which aim to encourage good programming practice. The limitations imposed by this system make it difficult to exhibit unstructured programs. Figure 6 shows the graphic style of this method applied to the example program. The general flow is from top to bottom passing from box to adjacent box. In the 'structure diagrams' used by Bowles (1977) emphasis is placed on the various levels of program hierarchy and the charts have the character of a family tree. Here the connecting lines do not strictly relate to the sequence of execution but show the relationship between program levels, indicating which blocks are subordinate to which. Figure 7 shows the example program laid out using this style. The order in which actions are processed at each level is left to right, crossing horizontally from box to adjacent box.

Fitter and Green (1979) give a number of useful guidelines for designers of notation, their first principle being that information encoded perceptually rather than symbolically should be relevant to the users needs. They also suggest that notations should restrict the user to forms which are comprehensible and redundantly recode important parts of the information. Codes should also reveal the underlying processes that they represent and be readily revisable. They note that it is difficult to measure up to all of these at once and that designers must use their intuition in seeking a compromise.

Clearly both the proposals of Nassi and Shneiderman, and the scheme used by Bowles place their priority on restricting chart makers to describing programs which conform to structured principles. These charts are intended primarily as aids in the design of tractable programs.

On the other hand we feel that charts intended primarily for exposition should emphasize the sequence of execution which can be shown most clearly by means of flow lines. We would maintain that the order in which the actions of a program are processed is very relevant to the chart readers needs, and this is a key factor in revealing the underlying operation of the program.

The present authors' method

The proposals of Garland (op. cit.) were taken as a basis for an earlier scheme (Johnson and Richards 1977). This scheme, which was used to document a long program, provides what we believe to be a reasonable style for flow charts produced to publication standard by a graphic designer. However it should be borne in mind that most flow charts start life as drawings made by programmers who may not have a high-level of
Figure 8. In the Richards & Johnson scheme junctions of less than a right angle represent the convergence of flows. Junctions at right angles or greater represent choices of direction.

Drawing the tangential curves used for converging flow lines in the Garland based scheme does require a certain degree of skill and the filling-in of the small nodes which replace the boxes of the ISO system is tedious. We have noticed that when these nodes are badly drawn, so that square shaped action nodes are indistinguishable from diamond shaped decision nodes, no real confusion results. Decision nodes are always accompanied by a caption indicating a choice together with diverging flow lines labelled either 'Yes' and 'No' or 'True' and 'False'.

Can we then dispense with nodes? As already stated the fundamental structures of programming are the sequence, selection and repetition of blocks and each structure produces a distinct configuration when its logical form is expressed by flow lines.

We believe that these configurations, together with captions, are sufficient to describe program structures clearly. It is unnecessary to add an additional level of redundant recoding in the form of different shaped symbols, as this will be of little, if any, benefit to readers and furthermore complicates chart preparation. Like Nassi and Shneiderman (op. cit.) and Bowles (op. cit.) we also believe it is unnecessary to differentiate graphically beyond the three fundamental programming structures.

It is helpful if a flowcharting scheme permits the addition of new structures without requiring existing parts of a diagram to be erased, thus allowing a degree of revisibility. Also filing and photocopying can be made easier if A4 sized sheets can be used rather than the larger sheets usually required for standard flow charts. If these smaller sheets can be used with the longest side vertical, reorientation is avoided when charts are bound in with related text matter.

A proposal aimed at meeting these requirements is outlined in the points listed below:

1. The main flow is top to bottom and should be represented by a line drawn down the left-hand side of the sheet. Short horizontals or 'posts' mark the ends.
2. Captions describing actions may be attached to the line by short dashes or 'pegs' placed at right angles to the flow.
3. The interpretation of flow line junctions is as given in Figure 8.
4. The entry to a peg or test and first entry to a loop is always from the top. These, and the conventions concerning the junction of flow lines make the direction of flow obvious. The need for directional arrows is thus avoided giving a less cluttered appearance to the flow chart.
5. 'Balloons' containing a single number can be pegged to any action. This number refers to a subordinate sheet where the action is described in more detail. For example, a balloon numbered 2 on a sheet numbered 3/1 would refer to sheet 3/1/2. A balloon on that sheet numbered, say 3, would refer to sheet 3/1/2/3 and so on. The master sheet in any given series is numbered 0 (zero). The zero is omitted from all subordinate sheets, that is, a sheet numbered say 5, is taken to be subordinate to sheet zero.
6. The caption associated with a balloon on a parent sheet becomes the title on the subordinate sheet.
sheet explaining the action in more detail. When captions appear in programming language or what is virtually computer acceptable code, requiring no further decomposition, they are shown in upper case letters only. Captions in upper and lower case letters imply any level of description above that of a computer programming language and will usually be associated with a balloon indicating a subordinate sheet. This means that most 'chains' of flow chart sheets lead to captions expressed in computer acceptable code, except where the translation from some high-level description into programming language is well understood by intended readers.

Figure 9 shows some of our proposals applied to the structured presentation of the example program. For a program of this small size it is sometimes convenient to put all the information on one composite chart as in Figure 10. There are psychological as well as practical limitations to the depth of nesting which can be displayed on one sheet. On both grounds a depth of three is suggested.

It may be noted that the style of these charts owes something to Henry Beck's London Underground diagram (Garland 1969).
Concluding remarks

We have tried in our proposals to consider the needs of both the chart reader on the one hand and the chart maker on the other. We believe the proposed scheme requires only a modest degree of drafting skill and that visually pleasing results may be obtained with it, especially if a squared grid underlay can be used. The examples shown in Figures 9 and 10 were drawn freehand in this way.

The scheme accommodates to some degree the principles of notation design offered by Fitter and Green (op. cit.) with the exception of restriction. Our scheme does not prevent the expression of unstructured programs. However as our intention has been to provide a means of exposition, rather than a design aid we feel that this principle can be justifiably sacrificed for the other benefits which are provided.

Readers should bear in mind that the Figures, excluding 5 and 8, purport to describe the same example program, and that the strikingly varied styles of the charts result mainly from differing design priorities.

1. Wright and Reid (1973), and others have examined the use of flow charts as an alternative to prose as a means of expressing complex rules. Flow charts have also been used as an aid to fault-finding (Adams 1978) and as a means of syntax analysis (Wiseman and Linden 1979).

2. BASIC has been chosen here because of its wide spread use, especially on small machines. Alcock (1977) offers an amusing introduction to this language, the entire text of which is handwritten and illustrated by the author.
3. It is not suggested that this example is a typical computer program. It has been chosen simply as a convenient means of demonstrating flowcharting techniques, not as a test of them.

4. This is the CACTI program developed for use in the preparation of cut-away and exploded technical illustrations based on orthographic views (Richards 1975).

5. British standards on thesis presentation require the use of A4 sized pages, bound by the longest edge (BS 1973b).

6. Chaplin (1974) has also made proposals for the documentation of hierarchical flow charts of structured programs.
Professional experience

1960-5 Apprentice Technical Illustrator
1965-6 Dunlop Technical Publications
1966-70 Freelance Illustrator/Designer
1970- Freelance practice continued part-time

Teaching experience

1966-70 Visiting lecturer, Coventry College of Art and Design
1970-7 Lecturer, Lanchester Polytechnic, Department of Design
1977- Senior Lecturer, Coventry (Lanchester) Polytechnic, Department of Graphic Design

Research experience

1972-5 Part-time research student
   MPhil of the CNAA
1979-80 Full-time research student
   PhD of the Royal College of Art, London
1980-4 PhD programme continued part-time

Freelance clients

General graphics
   Allesley Press
   Bass Charrington
   Birmingham Museums

Technical illustration
   Caludon Engineering
   Staveley Industries
Computer graphics
BBC Television
Covpak Designs
Equals Creative Marketing
Mabey and Johnson

Qualifications

City and Guilds of London Institute
1963 Intermediate Technical Illustration
1964 Final Technical Illustration
1976 Master of Philosophy Degree CNAA

Professional bodies

1965 Licentiate of the Society of Industrial Artists and Designers
1972 Member of the Society of Industrial Artists and Designers
1973 Member of the Institute of Scientific and Technical Communicators
1978 Fellow of the Institute of Scientific and Technical Communicators