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Compatibility among Medical Classification Systems: A Case Study in the Classification of Cardiovascular Diseases

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Since classification systems are at best compromises between opposing or conflicting views and requirements of different user groups, incompatibilities exist between them. Therefore, in this research investigation an attempt has been made to study the extent of compatibility among Medical Classification Systems with special reference to the Classification of Cardiovascular Diseases. The specific objectives in relation to the problem of research are to study: Compatibility (1) among universal classification systems; (2) among special classification systems; and (3) between universal and special classification system. The study of compatibility has been made at near-seminal level by the application of Normative Principles of the General Theory of Classification, and at the phenomenal level by classifying a set of a few hundred cardiovascular pathological conditions. Major findings and inferences based on the study have been given. Apart from the fact that compatibility between systems is either unidirectional and bidirectional depending on the features of the systems concerned, the study indicates that the Normative Principles can helpfully be utilised for studying compatibility.

The study has shown that conceptual compatibility is far more important than verbal compatibility, and also that freely faceted classification systems can be used as link/switching languages for achieving compatibility. (Author)

1. Preamble

Man's innate desire to find order in his universe has prompted him to design and develop classification systems for different purposes. This, perhaps, was influenced by his unconscious recognition that order was the basis or – at least – an important element of stability. As a consequence, he identified, and identifies even today, categories of concepts, actions, and things, and attempts to relate them to one was applied by him to everything he owned, did or thought. This, then, might be considered as the genesis or starting point for the design and development of library classification systems.

To begin with, classification systems so developed were "universal" in that they were not confined to the classification of a subject or few subjects but covered all the subjects in the universe of knowledge. These universal classification systems were necessarily of broad extension and small intension only. Some of the universal classification systems developed were the Dewey Classification, Universal Decimal Classification, Library of

Congress Classification, Bibliographic Classification of Bliss, Colon Classification, and Library-Bibliographical Classification.

While the Universal Classification Systems were very useful in organising macro-documents such as books, they were found to be inadequate for classification of micro-documents, trade catalogues, etc. This was because of the fact that microdocuments were of great intension. Further, the Universal Classification Systems could not keep pace with the growth of the Universe of Subjects – a manifold multidimensionally dynamic, turbulently growing continuum. In addition, they (the Universal Classification Systems) fell short of the needs of the specialists who required a classification system detailed enough for all concepts as well as for all conceivable relationships among them.

As a consequence, there was a spate of activity in the development of special classification systems for the classification of documents of special kinds, of special physical form – microfilm, phonograph record, etc – , and covering, individually, highly specialised subjects, such as Electronics, Management Science, Pathology, etc. In addition, in the sixties and thereafter, thesaurus development was taken up vigorously. Thus, during the last few decades, numerous vocabulary control devices such as special classification systems and thesauri were developed to suit the differential requirements of the different groups of specialists. The situation was similar in regard to the field of Medical Sciences also.

While it was expected that the prolific development of vocabulary control devices would facilitate better access to information, it created problems as the classification systems and thesauri caused hindrance to the exchange of indexed items and thereby to cooperation between information systems and services. This is because of the fact that since vocabulary control devices are designed and developed to satisfy particular purposes, a certain degree of incompatibility exists among them. Further, there is not as yet any generally accepted theoretical basis for selecting keywords and arranging them in lists of thesauri. Therefore, there was a need to study compatibility to facilitate correlation of the different vocabulary control devices. This, in turn, would create the possibility of switching from one vocabulary control device to another.

Some of the factors/imperatives which increased the pace of activities pertaining to compatibility and convertibility achievement were:

- Exponential growth of publications, currently referred to as the "Information Explosion";
- Increasing concern for costs and benefits;
- Increased concern for providing convenient access to documents and information to the users;
- Avoidance of duplication of effort;
- Need for reclassification;
- Growth of information networks;
- International collaboration and information exchange programmes, etc.

Whatever may have been the reason, numerous library and information scientists were involved in compatibility research. The focus of their studies pertain to:

- Methods for studying compatibility among vocabulary control devices;
- Problems of compatibility; and
- Methods for achieving compatibility among vocabulary control devices.

2. Research undertaken

As in the fields of Medical Sciences, tremendous advances have been made in recent times, it was therefore felt that a study of compatibility among Medical Classification Systems – as many have been designed – would be useful.

The specific objectives in relation to the problem of research are:

- 1) To study compatibility among universal classification systems in the field of Medical Sciences;
- 2) To study compatibility among special classification systems in the field of Medical Sciences;
- 3) To study compatibility between universal and special classification systems in the field of Medical Sciences.

In other words, the overall objective of the research study was to study compatibility among Medical Classification Systems. Since the field of Medical Sciences was rather a big field, it was felt that if the study was restricted to the sub-field “Cardiovascular diseases”, it would yield some meaningful results.

The research undertaken seems to be in conformity or, perhaps, anticipated as it were, one of the methodological recommendations of the Augsburg Conference on Classification Research which suggested research and development programmes in the area of “Classification as a user-oriented activity”. The specific relevant recommendation was “. . . To establish compatibility between and integration of existing classification systems and thesauri in order to promote ease of use of the many existing information systems” (2).

As a prelude to this investigation, it was proposed:

- a) To survey the methods for studying compatibility;
- b) To identify problems of compatibility; and
- c) To identify and study the methods for achieving compatibility.

This was considered necessary to facilitate the provision of an overview of compatibility research as well as aiding in the choice of the appropriate method/procedure to be adopted for the study.

3. Methodology/Procedure

The steps involved are:

- Choice of universal and special classification systems;
- Study of compatibility between the respective essential elements of classification systems;
- Study of compatibility with the Basis of Reference, at the phenomenal level, by the application of a set of Normative Principles;
- Study of compatibility, at the practical level, between classification systems by classifying a set of few hundred cardiovascular pathological conditions;
- Analysis of observations; and
- Consolidation of findings.

3.1 Choice of Universal and Special Classification Systems

The Classification Systems chosen for the study of compatibility were:

- a) Universal Classification Systems
 - *Universal Decimal Classification* (= UDC)
 - Colon Classification (= CC)
- b) Special Classification Systems
 - Standard Nomenclature for Diseases and Operations (= SNDO)
 - International Classification of Diseases (= ICD)

The criteria governing the choice of the above-mentioned universal and special classification systems were:

- Familiarity with the classification systems concerned;
- Features – enumerative and faceted – of the classification systems concerned.

3.2 Study of Compatibility between the Respective Essential Elements of Classification Systems

In relation to the study of compatibility between the respective elements of classification systems concerned, each classification system was studied in regard to its genesis, structure and the method adopted for classifying. Special points, if any, were also looked into. Once this was completed, correlation of the respective essential elements was attempted so as to create or establish a concordance between the systems concerned.

3.3 Study of Compatibility at Theoretical Level by Application of Normative Principles.

Compatibility between classification systems can be studied at the theoretical and at the pragmatic levels. At the theoretical level, it would be ideal if one could compare the respective theories forming the foundation of the systems. Unfortunately, most of the classification systems have no explicitly stated theories which could be compared. Therefore, as an alternative, it has been suggested (1) that one can apply a certain set of Normative Principles i.e. Postulates, Principles, and Canons and observe to what degree each of the classification systems conforms to them. Accordingly, the various Normative Principles derived from the General Theory of Classification as enunciated in the Prolegomena (3) have been applied to universal and special classification systems.

3.4 Study of Compatibility at the Pragmatic Level

At the pragmatic or practical level, the compatibility between the universal classification systems UDC and CC has been studied by classifying 459 compound subjects in the field of “Cardiovascular diseases”. In regard to compatibility between special classification systems on the one hand, and between universal and special classification systems on the other, the 544 cardiovascular pathological conditions enumerated in the SNDO schedule were taken as the representative sample for classifying. Individualisation and co-extensiveness were looked for in the class numbers/code numbers given by the various classification systems.

3.5 Analysis of Observation

The observations made on the basis of the study in regard to the classification systems concerned were analysed to cover the following aspects:

- Factors/features favouring establishment of concordance
- Conformity of classification systems to Normative Principles
- Compatibility between classification systems at Conceptual, Verbal and Sequence levels
- Factors contributing to compatibility
- Factors contributing to incompatibility

The results obtained in relation to classification of cardiovascular pathological conditions were statistically analysed using the z-test at 0.05 significance level when the critical value of z-statistic was 1.645.

4. Observations

4.1 Application of Normative Principles

The Normative Principles derived from the General Theory of Classification fall into the following categories:

- General Laws
- Laws of Library Science
- Canons of Classification for Work in the Idea Plane
- Canons of Classification for Work in the Verbal Plane
- Canons of Classification for Work in the Notational Plane
- Canons for Book Classification
- Postulates of Classification
- Principles for Helpful Sequence

Since the investigation was specifically in relation to classification systems, it was felt that it would be sufficient if the Canons for classification in the three planes – Idea Plane, Verbal Plane, and Notational Plane –, Postulates of classification, and Principles for helpful sequence were applied. Accordingly, they were applied on the classification systems chosen and their conformity or otherwise to them was studied. The observations are given in Table 1.

4.2 Compatibility at pragmatic level

4.2.1 Universal classification systems

It has been observed that Colon Classification yields more number of co-extensive numbers than UDC. This has been tested statistically using the z-test at 0.05 significance level when the critical value of z-statistic is 1.64. The differences between CC and UDC in relation to the extent of co-extensiveness would give rise to problems of conceptual and sequence incompatibility, though translation/switching compatibility will not be affected.

4.2.2 Special classification systems

In regard to Co-extensiveness, 60% of the SNDO numbers are co-extensive. However, the majority of the SNDO numbers (97.4%) are individualised or unique in nature. On the other hand, while coextensiveness is not applicable to ICD code numbers, it has been observed

that a large majority (80.5%) of subjects are represented by homonymous numbers. Due to the different degrees of conformity to coextensiveness and individualisation of SNDO and ICD, conceptual and sequence compatibility problems are likely to occur between them. However, translation or switching from SNDO to ICD would be possible though in the reverse direction from ICD to SNDO would be fraught with a large number of difficulties.

4.2.3 Universal and Special Classification Systems

In relation to coextensive representation, statistical tests have shown that the Universal Classification System CC yields a larger number of coextensive numbers than either SNDO or ICD. However, while in regard to individualised numbers the performance of CC and SNDO is similar, it is very poor in regard to ICD.

5. Findings of the Study

Some of the major findings and inferences of this study (4) are summarised below.

5.1 General

1) The Normative Principles derivable from the General Theory of Classification are applicable to all classification systems for the study of compatibility among them.

2) Classification systems which are in conformity with the General Theory of Classification have a good chance of compatibility among themselves.

3) Compatibility among classification systems is always in relation to a particular point of time. If, however, the systems are self-perpetuating and able to provide coextensive numbers always for subjects, compatibility between them is ensured for all time.

4) Compatibility among classification systems may be unidirectional, bidirectional or multidirectional.

5) Vis-a-vis Verbal Compatibility, classification systems using precombined descriptors may have to change frequently with changes in names occurring in the disciplines concerned. On the other hand, classification systems adopting a high degree of semantic factoring and thereby using elemental descriptors will not have a problem, since meanings of the fundamental terms would not frequently change.

6) Conformity to the Canons of Terminology by different classification systems does not automatically guarantee Verbal Compatibility among them. This may be attributed to the difference in the degree of semantic factoring between the composite terms used in the classification systems.

7) The degree of specificity followed by classification systems can be considered as an indicator of compatibility between them.

8) Freely-faceted schemes of classification can be used helpfully as link/switching languages for achieving compatibility among classification systems.

9) Freely-faceted schemes of classification are well-suited for development into integrated schemes covering various classification systems due to their intrinsic self-perpetuating quality.

Table 1: Conformity of UDC, CC, SNDO, and ICD to Normative Principles

Normative principles (a)	UDC (b)	CC (c)	SNDO (d)	ICD (e)
Postulate of Fundamental Category	Recognises space and time	✓	Recognises to a limited extent as there is a distinct recognition of topographical and aetiological axes	No distinct recognition
Rounds for Energy Level and Level cluster	Not recognised distinctly No clear indication of levels of manifestation No consistency in regard to level cluster	✓	No recognition Recognises level of manifestation though no distinct connecting symbol is given	No recognition Not applicable
Basic facet and Isolate facets	Recognises basic facet distinctly	✓	Basic facet is implied; Isolate facets recognised to a certain extent	Basic facet is implied, Isolate Facet not applicable
Concreteness	Recognises only Space and Time facets. Other facets are not separated and due to its DC core having many compound subjects	✓	Recognises to a limited extent	Not applicable
Principles for Facet Sequence	Generally follows, but a few violations are seen which is in consonance with UDC's non-conformity with Postulates of Fundamental categories, Concreteness, Level, and Cluster	✓	Generally follows though there are a few violations	Not applicable as it does not recognise facets as such
<i>Canons for work in ideaplane</i>				
<i>Canons for Characteristics</i>				
- Differentiation	✓	✓	✓	✓
- Relevance	✓	✓	✓	✓
- Ascertainability	✓	✓	✓	✓
- Permanence	✓	✓	✓	✓
<i>Canons for Succession of characteristics</i>				
- Concomitance	✓	✓	✓	✓
- Relevant Succession	✓	✓	✓	Partial conformity
- Consistent Succession	✓	✓	✓	Partial conformity
<i>Canons for Array</i>				
- Exhaustiveness	Limited extent	✓	Limited extent	✓
- Exclusiveness	✓	✓	✓	✓
- Helpful sequence	Generally follows, but there are a few violations vis-a-vis Principle of Spatial Contiguity	✓	Not fully conformed to in certain cases	Not applicable
- Consistent sequence	Achieved by use of common and special auxiliaries	Achieved by schedules of common isolates, and by use of devices such as (CD), (SD), (AD), Facet, Phase, Superimposition, Mnemonic devices, etc.	✓	Limited extent
<i>Canons for Chain</i>				
- Decreasing extension	✓	✓	✓	✓
- Modulation	Generally conforms, but, there are a few true violations. In some cases, there are apparent violations possibly due to adoption of Group Notation	✓	Generally conforms, but, there are a few violations possibly due to adoption of Group Notation	Not applicable

(a)	(b)	(c)	(d)	(e)
Canons for Filiatory Sequence				Not applicable as most of the basic postulates, principles, and canons are not conformed to
– Subordinate Classes	✓	✓	✓	
– Coordinate Classes	✓	✓	✓	
Canons for work in the verbal plane				
– Currency	Conforms to this Canon through its two committees FID/CA and FID/CCA	Adopts Semantic Factoring. Avoids use of precombined descriptors and hence may appear as violating this canon	Conforms to this canon through the individual committees of the American Medical Association	Conforms to this canon by the Revision Conferences of Specialists of the World Health Organisation
– Reticence	In a few cases, uses colourless terms to be in conformity with the Canon of Exhaustiveness	✓	Conforms to this canon through in a few cases colourless terms such as “Other disorders” are used to be in conformity with the Canon of Exhaustiveness	In a few cases, colourless terms are used to be in conformity with the Canon of Exhaustiveness
– Enumeration	Not used to full advantage	✓	✓	✓
– Context	Not taken complete advantage	Not taken full advantage	Not used to full advantage	Not used to full advantage
	(All the schemes of classification may have violated this canon sometimes for purposes of clarity at the individual isolate level)			
Canons for work in notational plane				
Canon of				
– Synonym	Generally conforms to this canon. However, there are a few instances of synonymous numbers	Generally conforms to the canon though there are a few instances of violations. This is partly due to the autonomy given to the classifier in synthesising class	Generally conforms to the Canon though there are instances of a few synonymous numbers	Synonymous numbers do not exist as such. But lack of specificity forces the classifier to choose among many broad numbers, if consistency is not maintained synonymous numbers result
– Homonym	Nearly 17.1% of the numbers in the schedule are homonymous	Generally conforms to the canon though there are a few violations	Generally conforms to the canon though there are a few violations	Incidence of violations is very high. 80.5% of the 544 subjects enumerated are represented by 96 homonymous numbers
– Relativity	✓	Apparent violations due to telescoping of arrays	✓	Partial conformity
– Hierarchy	✓	Apparent violations due to telescoping of arrays	✓	Partial conformity
– Mixed base	✓	✓	–	–
– Pure base	–	–	✓	✓
– Faceted Notation	✓	✓	✓	Non-conformity to this canon
– Coextensiveness	80% of the numbers are coextensive	95.1% of the numbers are coextensive	Partial	Not applicable
Canons for Mnemonics				
– Alphabetical	Used sparingly	Used sparingly	–	–
– Scheduled	Limited extent	✓	Limited extent	Used sparingly
– Systemic	Limited extent	✓	✓	Not applicable
– Seminal	Limited extent	✓	Limited extent	Not applicable
Canons for Growing Universe				
– Extrapolation in array	✓	✓	Non-conformity as there is no provision for extrapolation or interpolation in array and chain	Non-conformity as there is no provision for extrapolation or interpolation in array and chain
– Interpolation in array	Non-conformity	✓	Non-conformity as there is no provision for extrapolation or interpolation in array and chain	Non-conformity as there is no provision for extrapolation or interpolation in array and chain
– Extrapolation in chain	✓	✓	Non-conformity as there is no provision for extrapolation or interpolation in array and chain	Non-conformity as there is no provision for extrapolation or interpolation in array and chain
– Interpolation in chain	Limited extent	✓	Non-conformity as there is no provision for extrapolation or interpolation in array and chain	Non-conformity as there is no provision for extrapolation or interpolation in array and chain

10) While autonomy provided to the classifiers by the Freely-faceted schemes of classification has its advantages, it is likely to give rise to compatibility problems if consistency is not maintained.

5.2 *Compatibility between Universal Classification Systems*

While there seems to be overall compatibility between Universal Decimal Classification and Colon Classification, some of the features of the former give rise to some incompatibility. They are: The DC core; inadequacy in facet analysis; inadequacy of Colon device in the representation of passive and active relationships between concepts/classes, etc; inconsistency in the pattern of arrangement of compound subjects; non-conformity to some normative principles, etc.

The observations/findings on compatibility are:

1) Both the Universal Classification Systems, UDC and CC, are generally in conformity with the Normative Principles. By implication, both of them exhibit an overall compatibility with each other at the broad level.

2) CC is fully compatible with the UDC. But UDC is not fully compatible with CC due to either partial or non-conformity with the Normative Principles by UDC.

3) Autonomy provided to the classifiers by the freely-faceted classification systems like CC or almost freely faceted classification systems like UDC would give rise to compatibility problems due to the occurrence and/or synthesis of synonymous or incorrect isolate numbers and class numbers.

4) The various types of equivalences met with in relation to UDC and CC are:

- Precise equivalent
- Approximate equivalent
 - Broader
 - Narrower
 - Related
- No equivalent

5) Three types of incompatibility – Conceptual, Verbal, Sequence – are encountered between the universal classification systems UDC and CC.

5.3 *Compatibility between Special Classification Systems*

Despite the fact that SNDO and ICD are special Classification System covering subjects going with the specific subject “Human Diseases”, some compatibility problems are encountered between them. However, there seems to be overall correlation – though not conceptual – between them in that a large majority of compound subjects dealing with cardiovascular diseases are represented in both systems. The following are observations pertaining to concordance and compatibility:

1) In establishing concordance between SNDO and ICD, difficulties were encountered due to the differing features – faceted and enumerative, different structuring of the field as a consequence of differing purposes, differing levels of specificity, etc.

2) Compatibility between special classification systems SNDO and ICD is unidirectional from the former to the latter.

3) There seems to be overall correlation – though not conceptual – between the two special classification systems in that a large majority of compound subjects dealing with cardiovascular diseases are represented in both systems.

4) The differential structuring of the two special classification systems gives rise to conceptual incompatibility as well as sequence incompatibility.

5) While SNDO is, generally speaking, in conformity with the Normative Principles, ICD is either in partial conformity or in non-conformity with most of them leading to compatibility problems between them.

6) It is not always true that special classification systems give a detailed breakdown of the field. This leads to conceptual and sequence incompatibility.

7) The general impression that classification systems designed by specialists would be helpful in organizing information is questionable since different specialists belonging to one and the same medical specialisation may arrive at different sequences which may be helpful only to the particular group or groups concerned.

5.4 *Compatibility between Universal and Special Classification Systems*

In regard to compatibility between the universal classification system – Colon Classification – and special classification systems – SNDO and ICD –, it was expected that there would be difficulty. This is because the general impression is that the universal classification system will not have the same degree of specificity as that of special classification systems. But, the present investigation has shown a different finding. On the question of compatibility, it has been found that the universal classification system has an overall compatibility with only one of the special classification systems considered. The following are the observations/findings in regard to Concordance and Compatibility:

1) In establishing concordance between classification systems – universal and special –, some of the parameters to be considered are:

- a) Features – enumerative, faceted – of the classification systems concerned;
- b) Scope and structuring of the field concerned by the classification systems;
- c) Size of vocabulary of the systems;
- d) Level of specificity of the systems;
- e) Extent of individualisation achieved; and
- f) Co-extensiveness of the class numbers/code numbers.

2) A certain degree of Conceptual, Verbal, and Sequence incompatibility exists between CC and SNDO which, however, does not affect translation or switching compatibility.

3) Conceptual, Verbal and Sequence incompatibility exists between CC and ICD which affects translation or switching compatibility;

4) As a consequence, while compatibility between CC and SNDO is bidirectional, it is unidirectional from CC to ICD.

5) The specificity achieved in classification systems which has an impact on compatibility among them, is ob-

served to be greater in some universal classification systems when compared to that of some special classification systems.

6. Concluding Remarks

From the foregoing account, it becomes clear that the obsession about an apparent incompatibility between the attributes of universal classification systems covering the whole or nearly the whole of the Universe of Subjects and special classification systems covering smaller chunks of the Universe of Subjects is not valid. Further, the observation or inference drawn by many that classification systems cannot serve both shelving and bibliographical purposes does not hold good. This has been amply demonstrated by Colon Classification, a universal classification, in that it has been able to represent coextensively subjects of great extension as well as of great intension. As a matter of fact, its performance is as good as, if not better than SNDO and ICD. This has implication in that it (CC) does not contribute to compatibility problems with other classification systems. Further, its self-perpetuating quality, enables it to be considered as a fit candidate for developing it into an integrated scheme of classification.

On the question of studying compatibility among classification systems, this study has shown the large potential of the Normative Principles of the General Theory of Classification. It may be seen that classifica-

tion systems which are in conformity with them (as CC and SNDO) will be largely compatible with each other. But, for some of the Normative Principles such as, Canons of Mixed Base/Pure Base, Canons for Faceted/Non-faceted notation, Canons for Mnemonics, etc., most of the Normative Principles have an influence on compatibility. Therefore, they may be considered as Normative Principles for Compatibility. This, then, reaffirms the fundamentality of the Normative Principles of the General Theory of Classification.

Another possible benefit in studying compatibility among classification systems is that it would facilitate decision-making in choosing the appropriate classification system for organisation of a collection or of information in a particular library or information centre.

References:

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International Federation of Classification Societies

The foundation of the International Federation of Classification (IFCS) took place on July 4, 1985 at Cambridge, England. At present it consists of six members, namely: the British Classification Society, the Classification Society of North America, the Section Data Analysis and Numerical Classification of the Gesellschaft für Klassifikation, the Japanese Classification Society, the classification group of the Società Italiana di Statistica, and the Société Francophone de Classification. Prof. Dr. H.H. Bock, Aachen, was elected president. According to its statutes the Federation aims at scientific exchange, cooperation and information between all those interested in numerical methods and applications of classification, distribution of technical-scientific information in this field, preparation of international conferences, publication of monographs and journals. A first conference is foreseen for 1987 to be held in Europe.

4th European Meeting of the Psychometric Society and the Classification Societies

From July 2-4, 1985 the 4th European Meeting took place at Cambridge, England with some 234 participants from many countries. Some 130 papers were presented which were devoted to data analytical methods of

psychometrics (93) and numerical methods from the field of classification (37). The sections relating to classification were the following: 1) Hierarchical classification and pattern recognition, 2) Non-hierarchical classification, 3) Taxonomy and cladistics, 4) Micro-computer applications, 5) Assessment and comparison of classifications.

British Classification Society: Meeting Fall 1985

A one-day meeting will be held at Burlington House, London on Nov. 8, 1985 on the topic "Shape and Size in Classification". The president, Mr. J.C. Gower, will introduce the following speakers and papers: P.L. MAIN: Automatic classification of outline shape in archaeology - problems and developments. - I.O. ANGELL: An octree algorithm for the generation and display of symmetric shapes. - S. LAFLIN: Use of B-spline curves in classifying shapes. - R.J. WHITE: Comparison of Fourier and other methods for extracting shape descriptions from biological outlines for multivariate classification. - R. ALLKIN: The limitations of conventional biological shape descriptions in computer-assisted identification. M.R.B. CLARKE: A transformation of the normal distribution with applications to allometry. - For further information contact: R.W. Payne, Statistics Department, Rothamsted Experimental Station, Harpenden, Herts. AL5 2JQ, England.