



Hunt Institute for Botanical Documentation
5th Floor, Hunt Library
Carnegie Mellon University
4909 Frew Street
Pittsburgh, PA 15213-3890
Telephone: 412-268-2434
Email: huntinst@andrew.cmu.edu
Web site: www.huntbotanical.org

The Hunt Institute is committed to making its collections accessible for research. We are pleased to offer this digitized item.

Usage guidelines

We have provided this low-resolution, digitized version for research purposes. To inquire about publishing any images from this item, please contact the Institute.

Statement on harmful and offensive content

The Hunt Institute Archives contains hundreds of thousands of pages of historical content, writing and images, created by thousands of individuals connected to the botanical sciences. Due to the wide range of time and social context in which these materials were created, some of the collections contain material that reflect outdated, biased, offensive and possibly violent views, opinions and actions. The Hunt Institute for Botanical Documentation does not endorse the views expressed in these materials, which are inconsistent with our dedication to creating an inclusive, accessible and anti-discriminatory research environment. Archival records are historical documents, and the Hunt Institute keeps such records unaltered to maintain their integrity and to foster accountability for the actions and views of the collections' creators.

Many of the historical collections in the Hunt Institute Archives contain personal correspondence, notes, recollections and opinions, which may contain language, ideas or stereotypes that are offensive or harmful to others. These collections are maintained as records of the individuals involved and do not reflect the views or values of the Hunt Institute for Botanical Documentation or those of Carnegie Mellon University.

About the Institute

The Hunt Institute for Botanical Documentation, a research division of Carnegie Mellon University, specializes in the history of botany and all aspects of plant science and serves the international scientific community through research and documentation. To this end, the Institute acquires and maintains authoritative collections of books, plant images, manuscripts, portraits and data files, and provides publications and other modes of information service. The Institute meets the reference needs of botanists, biologists, historians, conservationists, librarians, bibliographers and the public at large, especially those concerned with any aspect of the North American flora.

Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

S.W.A.B. VII:

Dr. David Rogers
(University of Colorado, Boulder)

on

TAXIMETRICS

OF

CASSAVA

(MANIHOT)

Tues. Dec. 7

146 Robbins

12 noon

Grady - get copies of my earlier bibliography -

Introd. - effort to explain taximetrics by delimitation
one application - to the study or ~~study~~
of a biological species -

puts several taximetrics procedures to work -
emphasize that difference exists between
taximetrics and other subdivisions -

" is the methodology reflecting
the thought processes used in decision making -

Definition A species is an actual or potential ~~interbreeding~~ interbreeding
population composed of individuals sharing a
common gene pool -

or a cluster of organisms with the following properties

- 1 - cluster is separated from others -
- 2 - discontinuity has a genetic base with barriers
to prevent gene exchange with outsiders.

3 - members of cluster interbreed + share common gene ^{pool}
to delimit the species is to find clusters with these properties
or determining a subset of a larger set, the subset
exhibiting these properties.

Procedures - Fig. 1 - The overall picture -

Fig. 2 - typical procedures to begin the study
use of TAXIR

Fig. 3 - Study of phenotypic variation -

use of G.H.A.R.A.N.A.L

Go to ~~Fig. 4~~ [↓] Fig. 5
- Discovering taxa-
GRAPH-

The preliminary work is, in this case, only the beginning.

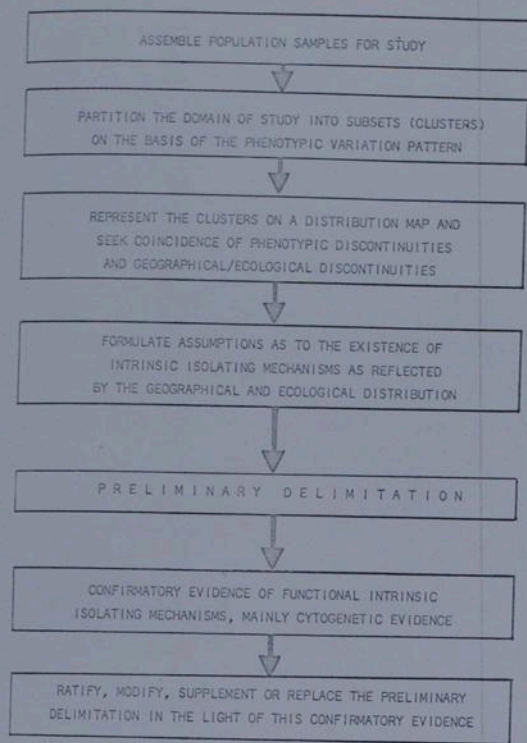
But - in most taxonomic output, this is the end -

Fig. 6 - Homogeneous clusters -
" 7 - Heterogeneous " .

The second phase for discovering or delimiting the biological species -

TABLE 1 -
and
finally
Fig. 8.

FIGURE 1. A summary of species delimitation processes

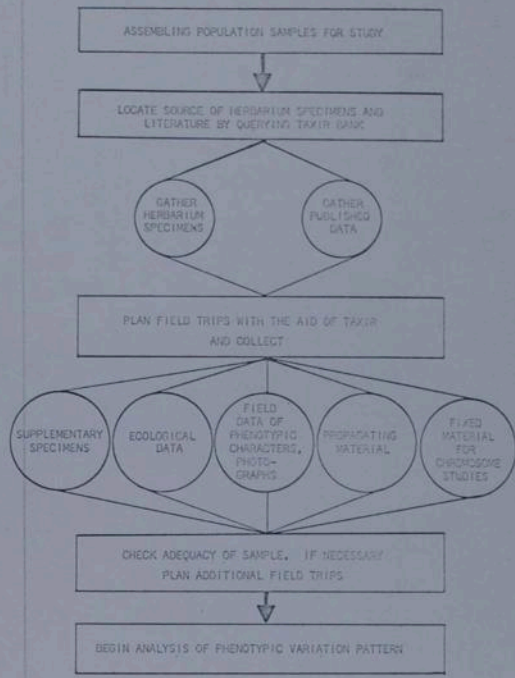


The quality of the classification depends on the adequacy of the sample. This has become especially significant in the light of the population/gene pool concept. Formerly a single sample (specimen) of a species was deemed to be adequate for study. Now, to define a species properly, it has become necessary to evaluate the variation patterns over the entire range of a species by analyzing hundreds of samples. The techniques of mass sampling of wild populations (Anderson 1941, 1943) are very effective for obtaining adequate representation of the phenotypic variation.

The use of Automated Information Retrieval Systems. Computer-aided information retrieval systems such as TAXIR (Estabrook and Brill, in press) would be of

STANFORD LIBRARY

Figure 2. A typical procedure to begin the study



significant help to taxonomists, particularly monographers, if adopted by the major herbaria of the world. There are probably over 100 million specimens in the world's herbaria (Lanjouw and Stafleu, 1964). This is a rich source of material for study, but unfortunately, proper use is not made of much of it, mainly because of the lack of knowledge about its availability. A central TAXIR data bank, if set up with the collaboration of all the repositories, would be of practical help to taxonomists, not only in assembling herbarium specimens, but also in planning field trips for supplementary collections and studies.

ANALYSIS OF PHENOTYPIC VARIATION PATTERN

Integration of evidence from diverse disciplines. A half century ago the phenotype was thought of largely in macroscopic terms. Today sophisticated techniques such as electrophoretic "protein signatures" (Randall 1968) are being employed to evaluate

study. Detailed distribution maps of the population samples are prepared depicting both geographical distribution and ecological habitat. Indicate the major clusters on the map by representing members of each cluster with different colors. The next step is to find suggestive evidence from geographical and ecological distribution patterns indicative of the possibility of interbreeding among members of a cluster and isolation preventing gene exchange with outsiders. The worker should be aware that the distribution map is only as good as the sample used in the study. Large gaps within otherwise contiguous range may merely represent the lack of collections from that area.

DESIGNATIONS OF TAXA

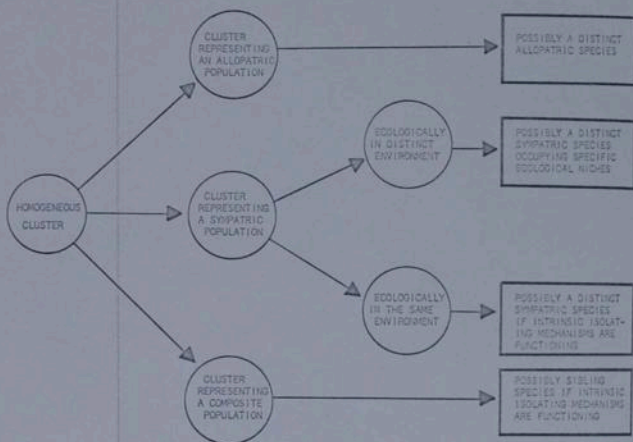
The "moat" of the clusters, the "C-value" at which members of a cluster join together, the "internal connectedness" of clusters, and the progressive behavior of the clusters in the subgraphs significantly aid in strengthening the ability of the specialist in delimiting taxa. The specialist should be sufficiently familiar with the processes to use them as guides to effectively delimit his taxa.

Homogeneous clusters (Fig. 6)

1. *Allopatric species*. If a cluster represents a population sufficiently integral (conducive to interbreeding), disjunct from other populations (suggesting gene exchange barriers), and the other indications given in the preceding paragraph also corroborate, such an homogeneous cluster may be delimited as a distinct allopatric species.

2. *Sympatric species*. If the homogeneous cluster represents a sympatric population, a survey of possible isolating mechanisms will become necessary. The most common

FIGURE 6. Homogeneous clusters and taxon designations



ecological isolation, and this will become apparent if the population samples occupy specific habitats. Ecological information, if at all recorded with herbarium specimens, is in most cases meager, and supplementary ecological data would frequently become essential. Other kinds of isolating mechanisms such as seasonal, ethological, mechanical, etc. may also be of critical importance. If one or more types of isolating mechanisms are functioning, and if there are corroborative indications in the subgraph, the cluster may be a distinct sympatric species.

3. *Sibling species*. Sometimes a homogeneous cluster may consist of two or more species which have close phenotypic similarity. They can be distinguished by detailed examination of additional phenotypic attributes and by discovering functional isolating mechanisms.

Heterogeneous clusters (Fig. 7)

Since natural populations are dynamic, ever-evolving entities, a heterogeneous cluster may represent populations at any one, or a combination, of the following intergrading stages of speciation:

1. a heterogeneous population, representing one dynamic species,
2. an evolutionarily intermediate population, showing varying levels of primary speciation at different regions within its range,
3. a polytypic species composed of subspecies, ecotypes, or other infraspecific taxa,
4. a cluster of populations each representing a species,
5. a population undergoing secondary speciation.

Although it is very difficult to determine accurately the exact stage of speciation of a given population, an estimate, at least with a reasonable degree of accuracy, is

FIGURE 7. Heterogeneous clusters and taxon designations

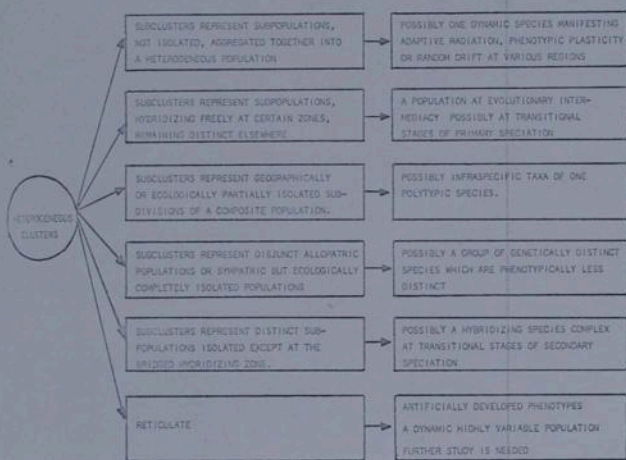
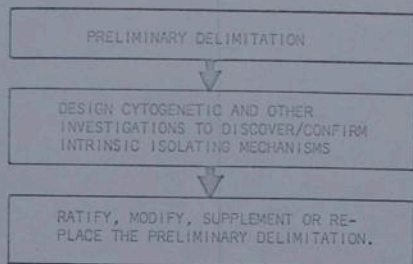


FIGURE 8. Integrating confirmatory evidence of intrinsic isolating mechanisms



When related sympatric species, giving allowance for the phenomenon of character replacement, may be taken as an index to the probable presence or absence of intrinsic isolating mechanisms. This may be the best available procedure in such cases.

VERSATILITY OF TAXIMETRIC METHODS

One of the most important purposes of a classification is to function as an information-preserving structure. The best system of classification is the one that best meets the purposes of the user. The modern biological species concept is the most meaningful to the biologists today, and as correctly pointed out by Mayr (1957), no biologically trained taxonomist would like to be considered as a pebble-sorter. But, as a palaeontologist, this concept is not easily applicable. To a microbiologist, biochemical and physiological criteria may be more meaningful, and to a nonbiologist, such as a geologist, this species concept is completely irrelevant.

The basic taximetric methods are versatile enough to be applied by specialists in several varying fields. Taximetric methods have been successfully applied in different areas within the framework of different concepts such as: species delimitations, classification of cultivated plants, classification of ecosystems, and classifications in the fields of anthropology, geology and psychology.

References

- ESTABROOK, E. 1941 — The technique and use of mass collections in plant taxonomy. *Ann. Missouri Bot. Garden* 25: 287–292.
- ESTABROOK, E. 1943 — Mass collections. *Chron. Bot.* 7: 378–380.
- ESTABROOK, G. F. 1966 — A mathematical model in graph theory for biological classification. *J. Theor. Biol.* 12: 297–310.
- ESTABROOK, G. F. 1967 — An information theory model for character analysis. *Taxon* 16: 86–97.
- ESTABROOK, G. F. and R. C. BULL. 1969 — The theory of the TAXIR accessioner. *Math. Biosci.* (in press).
- ESTABROOK, G. F. and D. J. ROGERS 1966 — A general method of taxonomic description for a computed similarity measure. *BioScience* 16: 789–793.
- MAST, V. 1957 — The plant species in theory and practice. In E. Mayr (ed.), *The Species Problem*, Amer. Ass. Advan. Sci. Publ. No. 50, Washington, D.C., p. 39–80.
- ROGERS, D. J., G. F. ESTABROOK and D. J. ROGERS 1968 — Application of an information theory model for character analysis in the genus *Arceuthobium* (Visceaceae). *Taxon* 17: 605–619.

SOME READINGS IN TAXIMETRICS

GENERAL

1. Rogers, D. J. 1963. Taximetrics--new name, old concept. *Brittonia* 15: 285-290.
Where "taximetrics" was first used and defined.
2. Rogers, D. J., H. S. Fleming and G. Estabrook. 1967. Use of computers in studies of taxonomy and evolution. In *Evolutionary Biology*, Vol. I, 169-196. Eds. Dobzhansky, T., M. K. Hecht, and W. C. Steere. Appleton-Century-Crofts.
This paper gives the general background for development of taximetrics, although the title is misleading. We give some historical background, rationale in mathematics, descriptions of computers and programming, and the various categories in evolutionary and taxonomic work where computers had been applied up to that time.
3. Rogers, D. J. and S. G. Appan. 1969. Taximetric methods for delimiting biological species. *Taxon* 18: 609-624.
Herein, we describe the integrated use of all of our methods to aid in the study of biological species. The methods themselves do not delimit the biological species, but point to the step-wise procedures which, if followed, are powerful techniques in guiding the discovery (or delimitation).

TAXIR

1. Estabrook, G. F. and R. C. Brill. 1969. The theory of the TAXIR accessioner. *Math. Biosciences*. 5: 327-340.
This paper gives the mathematical basis for the TAXIR Information retrieval system. A powerful method to store the information, address the information, and retrieve it is described.
2. Rogers, D. J. 1970. Theoretical and practical considerations on data structuring for a computerized information retrieval system. In *Archeologie et Calculateurs* (Marseille). pp. 145-159. Editions du Centre National de la Recherche Scientifique. 15, Quai Anatole-France. Paris VII^e.
I compare the information systems employed by systematic curators with the model we developed, and indicate some of the methods to prepare data for storage.

CHANAL

1. Hawksworth, F. G., G. F. Estabrook and D. J. Rogers. 1968. Application of an information theory model for character analysis in the genus Arceuthobium. (*Viscaceae*). *Taxon* 17: 605-619.
The methods of use of the character analysis program are described in biological terms, and the application of the findings made for the value of the characters to be employed in the classification of Arceuthobium.

2. Estabrook, G. F. 1967. An information theory model for character analysis. *Taxon* 16: 86-97. The mathematical arguments for this program are given.
3. Fleming, H. S. and D. J. Rogers. 1970. A classification of Manihot esculenta using the information carrying content of a character as a measure of its classificatory rank. *Proc. Int. Symp. Trop. Root Crops (Hawaii)*. pp. 66-70. This interesting application of the character analysis program indicates that it provides another method of classification, in addition to the power as a character analytic technique.

GRAPH

1. Wirth, M., G. F. Estabrook and D. J. Rogers. 1966. A graph theory model for systematic biology, with an example for the Oncidiinae (Orchidaceae). *Systematic Zoology* 15: 59-69. This paper describes in taxonomic terms the clustering methods developed in the Taximetrics Lab. The paper does not attempt to deal with the mathematical arguments.
2. Estabrook, G. F. and D. J. Rogers. 1966. A general method of taxonomic description for a computed similarity measure. *Bioscience* 16: 789-793. This paper describes the important process for structuring characters to be used in classification.
3. Estabrook, G. 1966. A mathematical model in graph theory for biological classification. *Jour. Theor. Bio.* 12: 297-310.
4. Irwin, H. S. and D. J. Rogers. 1967. Monographic studies in Cassia (Leguminosae-Caesalpinioideae). II. A taximetric study of section Apoucouita. *Mem. N.Y. Bot. Gard.* 16: 71-118. This is one of our first applications of the GRAPH clustering model. The section Apoucouita of Cassia contained some of the most complex classificatory problems in this large genus, and the computer model proved of great assistance in sorting out the specific and sub-specific taxa.
5. Prance, G. T., D. J. Rogers and F. White. A taximetric study of an angiosperm family: generic delimitation in the Chrysobalanaceae. *New Phytol.* 68: 1203-1234. Four computer methods were compared for their capacity to make classifications, and our GRAPH model came out on top. In this case, we were comparing genera within a family.
6. Arp, G. and D. J. Rogers. 1970. A computer-aided classification of the varieties of Pediocactus simpsonii (Engelm.) B. & R. *Cactus & Succ. Jour.* 42: 40-43. An intraspecific study of a cactus species.
7. Stearn, W. T. 1971. A survey of the tropical general Oplonia and Psilanthele (Acanthaceae). *Bull. Br. Mus. (Nat. Hist.) Botany*. IV (7): 259-323, plates 38-47. Stearn used our GRAPH model to aid in this study, particularly with the genus Oplonia.

8. Rogers, D. J. and H. S. Fleming. 1972 (In press) Economic Botany. A monograph of Manihot esculenta. The GRAPH model was our chief method to sort out the complex relationships within a cultivated species. The methods of use, and several suggestions on the intraspecific problems of cultivated plant taxonomy are described in sufficient detail so that workers can fully grasp our concepts.