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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.

List of Participants in the Numerical Taxonomy Conference

The University of Kansas, Lawrence
November 1967

Dr. G. H. Ball
Radio Systems Laboratory
Stanford Research Institute
Menlo Park, California 94025

Dr. A. S. Boughey
Department of Population and
Environmental Biology
University of California, Irvine
Irvine, California 92664

Dr. J. H. Camin
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dr. T. J. Crovello
Department of Biology
University of Notre Dame
Notre Dame, Indiana 46556

Dr. M. V. Dale
c/o Dr. L. Orloci
Department of Botany
University of Western Ontario
London, Ontario, Canada

Dr. J. C. Davis
Geological Survey
The University of Kansas
Lawrence, Kansas 66044

Dr. D. C. Eades
School of Life Sciences
Morrill Hall
University of Illinois
Urbana, Illinois 61801

Dr. P. R. Ehrlich
Department of Biological Sciences
Stanford University
Stanford, California 94305

Dr. G. F. Estabrook
Department of Biology
University of Colorado
Boulder, Colorado 80302

Mr. J. F. Farris
Museum of Zoology
University of Michigan
Ann Arbor, Michigan 48104

Mr. D. R. Fisher
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Mr. H. P. Friedman
IBM
590 Madison Avenue
New York, New York 10022

Dr. D. D. W. Goodall
Department of Population and
Environmental Biology
University of California, Irvine
Irvine, California 92664

Dr. M. P. Johnson
Department of Biological Sciences
Kent State University
Kent, Ohio 44240

Dr. R. Johnston
Department of Zoology
The University of Kansas
Lawrence, Kansas 66044

Dr. R. L. Kaesler
Department of Geology
The University of Kansas
Lawrence, Kansas 66044

Mr. J. R. L. Kishpaugh
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dr. W. R. Lockhart
Department of Bacteriology
Iowa State University
Ames, Iowa 50010

Dr. D. F. Merriam
Geological Survey
The University of Kansas
Lawrence, Kansas 66044

Dr. C. D. Michener
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dr. H. Morishima
National Institute of Genetics
Yata 1.111, Sizuoka-ken
Japan

Dr. W. W. Moss
Department of Entomology
Academy of Sciences
19th and the Parkway
Philadelphia, Pennsylvania 19103

Dr. P. M. Neely
Section of Biostatistics
Presbyterian St. Luke's Hospital
1753 West Congress Parkway
Chicago, Illinois 60612

Dr. L. Orloci
Department of Botany
University of Western Ontario
London, Ontario, Canada

Dr. D. J. Rogers
Taxometrics Laboratory
Department of Biology
University of Colorado
Boulder, Colorado 80302

Dr. F. J. Rohlf
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dr. A. J. Rowell
Department of Geology
The University of Kansas
Lawrence, Kansas 66044

Dr. J. W. Rowen
General Research Corporation
6300 Hollister Avenue
P. O. Box 3587
Santa Barbara, California 93105

Mr. J. Rubin
IBM
590 Madison Avenue
New York, New York 10022

Mr. M. Sackin
MRC - Microbial Systematics Research Unit
University of Leicester
University Road, Leicester
England
(at Geological Survey, University of Kansas, until June 1968)

Dr. G. R. Smith
Department of Zoology
The University of Kansas
Lawrence, Kansas 66044

Dr. P. H. A. Sneath
MRC - Microbial Systematics Research Unit
University of Leicester
University Road, Leicester
England
(at Department of Entomology, University of Kansas, until 15 March 1968)

Dr. R. R. Sokal
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dr. P. V. Wells
Department of Botany
The University of Kansas
Lawrence, Kansas 66044

Mr. W. J. Wrenn
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

NOV 8 1967

Memo on Numerical Taxonomy Conference

FROM: Mrs. Connie Meister
(Secretary to Dr. Sokal)
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Rohlf's office 913-864-4051

Dr. Sokal's office phone: 913-864-3706

Dr. Rohlf's home phone: 913-843-4468

NOTE: Dr. Sokal will be unavailable on Sunday, 12 November until 9:00 p.m.

TO: Dr. Rogers

☐ 1. We have not as yet received a reservation form from you. Please let us know right away whether and when you are coming.

☐ 2. Are you coming to the mixer and/or the dinner?

TRANSPORTATION TO LAWRENCE

So many persons are coming by rented car that it should be possible to find rides for those that planned to come by bus. Below we hope to arrange these rides as simply as possible.

☐ 3. You indicate that you plan to rent a car. Could you furnish a ride for

_____ planning to arrive on _____ at _____?

_____ planning to arrive on _____ at _____?

_____ planning to arrive on _____ at _____?

These persons have been instructed to wait for you at the information counter of the airline bringing you to Kansas City (_____). If delays or changes of plan result, you as well as they should leave messages at that counter. Unless we hear from you to the contrary, we shall assume that you are agreeable to furnishing transportation for the above named persons.

☑ 4. We are asking

Mr. J. T. Farris arriving on TWA 529 at 4:52 pm

to furnish you a ride to Lawrence. Meet him at the information counter of his airline. If delays or change of plans result, you as well as he should leave messages at that counter.

RESERVATIONS

A room has been reserved for you at the Eldridge Hotel

for the nights of 12-13 November, 1967, at the rate of $7.50 per night.

☒ 5. Remember that to retain the informality of the proceedings, we are not providing projection equipment. If you wish to share your results with us, please bring them in the form of handout sheets. Provide about 40 copies of the material to be handed out.

THE UNIVERSITY OF KANSAS · LAWRENCE, KANSAS · 66044

DEPARTMENT OF ENTOMOLOGY · SNOW ENTOMOLOGICAL MUSEUM

7 December 1967

Professor David J. Rogers
Taxometrics Laboratory
Department of Biology
Armory 101
University of Colorado
Boulder, Colorado 80302

Dear Dave:

Many thanks for your kind letter and also for the nice words to the University Administration. We are glad that you felt the conference was a success. Thank you also for your valuable reprints which are very necessary to Peter and myself in revising the book.

We are looking forward with much anticipation to the conference next year. We probably want to keep in touch on arrangements for the conference regarding topics and so forth. While the arrangements here might have been satisfactory for a first such conference, possibly at a follow-up meeting we might wish to be more specific about topics to be discussed and we might also wish to consider whether more formal presentations are in order.

Best wishes, also to George Estabrook.

Sincerely yours,

Bob

Robert R. Sokal
Professor of Statistical Biology

RRS:cm

15 November 1967

The President
University of Kansas
Lawrence, Kansas 66044

Dear Sir:

I write to express my appreciation for the many courtesies that the University of Kansas extended to the members of the Conference on Numerical Taxonomy held in your Student Union on November 13 and 14. It was an exceptionally well organized conference and all of the supporting people should be congratulated for making our stay so very pleasant.

I am sure that this conference will be looked upon in the future as having had great impact on an important aspect of modern biology. I was honored to be considered as a member of this conference.

Sincerely yours,

David J. Rogers
Professor of Biology

DJR:gm

15 November 1967

Dr. Robert Sokal
Department of Entomology
University of Kansas
Lawrence, Kansas 66044

Dear Bob,

The enclosed epistle to your President expresses my ideas about the conference.

In keeping with your request I am sending herewith another copy of all our papers. In addition to these published papers, the following activities are being presently investigated.here.

1. An information retrieval system for Biology. Description of this work is probably in the hands of Professor Michener. I would be pleased if you would ask him to share his copy with you for an explanation of our activities with respect to this work.

2. A manuscript submitted to the Association for Computing Machinery, "Compressed X Functions as Inverted Information Files," by Estabrook and Brill. Abstract: A procedure is described for storing and retrieving information in inverted files such that 1) a large number of search criteria may be stored, 2) using the information theory minimum of storage space, and 3) retrieval is effected by direct boolean arithmetic on the stored information.

We will pleased to have a conference here approximately one year from now. I trust that you will share with us at any time any ideas which you may have concerning this conference.

George and I enjoyed ourselves tremendously and received much valuable information from the conference. Many thanks to you and Jim Rohlf.

Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

20 November 1967

Dr. Kenton L. Chambers
Systematics Program
National Science Foundation
Washington, D. C. 20550

Dear Ken:

I promised in St. Louis to give you a resume of the meeting of numerical taxonomists which was held in Kansas in the beginning of last week (November 13 and 14). The reason for giving you this report is to refresh your memory about what is going on in the field, so that more intelligent funding of numerical taxonomy projects may be made. You know that I feel very strongly that NSF systematics panels have usually been relatively harsh in dealing with numerical taxonomy for reasons not necessarily related to the value of the research. Much of the criticisms of numerical taxonomy has been on an emotional basis on both sides of the fence. It is not clear to me why some spokesmen for the use of various mathematical methodologies and computers for taxonomy have felt that they had to make relatively derogatory remarks about the people who were not so interested. I need not tell you who these people are for I am sure you can fill in the blanks.

Therefore it is a pleasure to be able to report that when workers in this type of endeavor are amongst themselves and their kind, you find them to be solid citizens, much interested in the fundamental aspects of the science of taxonomy. What is going on now is a very deep and thorough investigation of the tenets in the field, to discover if there be some basic assumptions, rules and procedures by which we can elevate the science of taxonomy from an intuitive process to one which can be expressed in some more precise manner.

The sessions that were held in the two day workshop attended by some thirty people were devoted to the following:

1. The overall philosophy of numerical taxonomy (and read here for Numerical taxonomy theoretical taxonomy),

2. The best structuring of characters for use in numerical taxonomy,

3. Optimization of the information for classification, and

4. Methodology for phylogenetic investigation, taxonomic keys, and information retrieval.

It is noteworthy that in these sessions the thinking processes which taxonomists have long said could not be quantified were the major effort

of the group. Very little was said about the more mechanistic aspects of the hardware. This is indeed an interesting development because it indicates confidence amongst the group that we now have in the computers effective tools to carry out our intentions. Perhaps this is not generally known to the taxonomic community (I am sure it is not) but amongst the group present there was no quarrel with whether we should or should not use computers, in the same sense as to whether we should or should not use biosystematic evidence for classifying or use electron microscopes to discover more accurate detail.

Now the problem of how to discover who is or is not doing useful investigation in the field of numerical taxonomy becomes increasingly difficult because there are so many people becoming interested in this area, with so many disciplinary backgrounds, we cannot always be certain at this stage of the game whether a particular activity is new or redundant. This problem is, I think, one common to most developing disciplines and is not necessarily confined to numerical taxonomy. Therefore I suggest that in the considering of support for endeavors in this field that considerable leniency be allowed for a period of, say, ten years. In that time we will have developed sufficient background to be able to say with some certainty whether a particular research proposal contains new and interesting basic science or is just pedestrian copying.

Over the years observing the NSF systematics program I think I can say that the conservative group has allowed the minimum of support for the development of the basic science. No allowance was made if a worker strayed from some well-established pathway. It is most disturbing to see one group of taxonomists attacking another group of taxonomists concerning new aspects of the same discipline. This is particularly disturbing because it fragments the field in the view of more "modern" disciplines who will allow in their midst any variation. I must say at once that many of the attacks of molecular biologists against the classical taxonomy has been vicious and unscientific but on the other hand also say that taxonomists themselves have brought much of the contention down on themselves for failure to keep abreast of modern thinking and the opportunity to employ some devices for their benefit. Since no field of effort is ever worked out we should constantly be on the lookout for ways to improve the science which we follow.

We will have to support graduate students and investigation in numerical taxonomy in order that this field be allowed to settle itself in among the other subdisciplines of taxonomy (by subdisciplines I refer to chemotaxonomy, biosystematics, etc.). We are going to have to support postdoctoral fellowships which will allow workers to go to the centers where numerical taxonomy is being done to learn methodologies and theoretical aspects. NSF and the systematics community should be the leaders in this field rather than dragging its heels and bickering about non-useful arguments.

It is not my opinion that numerical taxonomy intends to eliminate other kinds of taxonomy. It is rather my opinion that it will be a supporting endeavor to taxonomy adding both to fundamental theoretical levels and in solving the many still unresolved taxonomic problems.

We can benefit by using computers in floristic studies, in developing computer keys for identification of unknowns, for aiding curators in their busy work of keeping up with the many tasks imposed on these fellows by their multiplying record=keeping requirements, provide information retrieval systems about the organisms in which we are so interested, and perhaps even in teaching taxonomy.

As you can see from this, my report to you is more of an opinion than a factual summary of the papers presented. One of the interesting facts that you should know about is that at this meeting, although financed by the individuals who attended, a good 50% of the people there were from other countries. This, to me, is a reflexion on American taxonomists who refuse to examine what has to be done, and the potentialities in this field.

Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

NT 13/11/67 - AM -

Ehrlich - Perception literature - diff. cultures descr. things differently.
Unused noise - it is not to be considered in "same way as before"

Lockhead - Opposite view from E's for musicians.

Sokal - new studies of niches -
Stages of development in NT -
1. Techniques -
2. Robust, established, now use.

Session IV

Jarvis – coherence correlation coeff –

Orig. notes $\rho \rightarrow$ dendrogram $\rightarrow$ new E

$C = E - P$

$r(P, E) = \frac{1}{\sqrt{1 + f_2(c)/k(k-1)}}$

f_2

Ball – Stanford Res.

Graphic display for graphs –

Prof. Bonphey – Taxonomic Keys –

Rolf Edelwood — Info. Statistics

Fabics –

Send reprints, directions of recent applications of our methods, to Sokal & Sm.

Ask Peter whether he has additional things to say about "info. stats."

C O P Y

Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

23 December 1966

Dr. E. R. Leach
Chairman, Classification Society
Department of Archaeology and Anthropology
The University
Cambridge, ENGLAND

Dear Dr. Leach:

I am writing you as a result of some recent talks which I have had with a number of persons in various disciplines who are interested in classification problems. Specifically, I attended a colloquium earlier this month in New Orleans, and just two weeks ago we had an international colloquium on classification and computer problems in geology and related sciences at The University of Kansas organized by Dr. Dan Merriam and attended by no less than 150 people. As you are undoubtedly aware, the interest in classification and its principles and procedures continues to grow at a truly remarkable rate, and this interest as well as the theoretical and practical importance of these problems is bound to increase. Comparing what we do in biological numerical taxonomy with the approaches of workers in the social and earth sciences, one finds much that is of common interest and mutual relevance. Unless we make attempts at cross-fertilization through the establishment of some inter-disciplinary approaches at this still formative stage of the development of classificatory theory and practice, the field of classification will surely split apart into numerous sub-disciplines, each one subject matter oriented, and entailing considerable amounts of duplication of effort. I would hate to see this happen, especially in view of the fact that some of our best ideas in biology have been adopted from workers in related fields. My colleagues in various disciplines and I feel that the time is right for workers in classification in North America to unite in a common society to the ends outlined above.

In fact, however, it is for these very purposes that our Classification Society has been founded, and judging from correspondence with Peter Sneath and also from the Bulletin, the Society is fulfilling its function admirably in Great Britain. However, the present arrangement leaves those of us in North America without a forum for presenting papers and exchanging views. There are many Americans who are prime

candidates for membership in the Society who have not even heard of it. It would be difficult to persuade them to join unless there were more tangible benefits such as the opportunity to exchange information at meetings and the possible publication of a journal.

What I would like to suggest, therefore, in an exploratory way, is whether our Society should try to expand and reorganize, making it a truly international society with active chapters at least in Great Britain and North America for a start. Several other societies that I know of could serve as models. Especially pertinent would be the Biometric Society which is divided into several national regions with regional as well as international officers and a council composed of representatives of the various regions. Since we are a far smaller society and likely to remain so in the foreseeable future, a less formal organization might possibly suffice. Thus, for example, we might have a chairman and a vice-chairman alternating annually between our two countries. Each of these officers might preside over the Society's meetings in our respective countries with a common secretary and editor to publish the Bulletin.

Clearly, such plans would have to be brought before the membership of our Society as they would involve consitutional changes. I do feel, however, that the benefits that would accrue to us by becoming functionally international would be considerable. Not only would classificatory work in North America be stimulated and receive more proper recognition, but every few years we could also attempt to hold an international meeting of some sort at which the conjunction with some other appropriate group. Secondly, I believe that we could greatly increase our membership in the United States and Canada. This, in turn, might well provide sufficient income to launch a modest journal, "Classification." I believe that the need for such a journal exists already and have no doubts that it would succeed. In view of the generally lower publishing costs in the United Kingdom, I would suspect that such a journal should be published and edited in England.

I look forward to hearing from you regarding the suggestions in my letter. If you and your committee will encourage me to go ahead, I can, I believe, with the help of some of the other American members of the Society, organize a considerable membership drive in North America.

With best wishes.

Sincerely yours,

Robert R. Sokal
Professor of Statistical Biology

RRS:cm

cc: Professor Gilmour
Dr. Sneath

C O P Y

University Botanic Garden,
Cambridge,
England.

4 November, 1967.

Prof. R. R. Sokal,
Entomology Department,
University of Kansas,
Lawrence, Kansas, U.S.A.

Dear Bob,

First, many apologies for the long delay in dealing with your letter to Edmund Leach of last December, and your follow-up of 11 October. As I said in my recent cables, we have now been able to discuss your letters at the AGM of the Society held on Thursday, 2 November, and the members present were very sympathetic to your suggestion for some form of N. American "branch" of the Society. We discussed in detail various possible arrangements and, in the end, came up with the following suggested scheme for the consideration of our N. American members: -

(1) Keep one Society, with a Chairman and Vice-Chairman alternating between the two areas, as you suggested.

(2) If we keep one Society, we shall presumably have to have some sort of joint Council to take important constitutional decisions, normally by correspondence!

(3) Each area to have a secretary, an area committee, and a treasurer, with separate finances. The secretaries' jobs would be to arrange meetings and recruit members in their respective areas. We discussed the idea of continuing with one treasurer and one banking account, but, on balance, the difficulties of this (e.g., the single treasurer having frequently to contribute small sums for meetings, postage, etc. to the secretary in the other area) seemed greater than those of having two separate treasurers and accounts.

(4) One publication for the whole Society, edited by a single editor in one or other of the areas. The size and nature of the publication would depend on the resources available. The cost of the publication would presumably be met jointly from the two accounts in proportion to the number of members contributing to each.

The above tentative scheme is put forward for your frank consideration and criticism - don't hesitate to say if you think it is not workable! Presumably we can make no "official constitutional" change until the next AGM (see item 13 in our present Constitution, Bulletin No. 1, p. 36), so there is plenty of time for discussion. It is particularly fortunate that Peter Sneath is with you, and I am sure he will have some ideas on

the problem. In the meantime, the A.G.M. did not, of course, see any objection to your organizing a Symposium in the States under the auspices of the Society; our finances are reasonably healthy, and if you wanted a small contribution towards the cost of such a symposium, it would at least be an interim gesture towards our trans-Atlantic friends!

When we have all agreed what we think is a workable scheme, we must, I suppose, be looking ahead to the actual chaps who might be able and willing to fill the various posts on both sides of the Atlantic!

I am sending a copy of this letter to Peter, plus a copy of Bulletin No. 3, which may not have reached him.

With best wishes,

Yours ever,

J. S. L. Gilmour
Director

Conference on Numerical Taxonomy

At the recent Systematics Symposium at Ann Arbor, several workers in numerical taxonomy agreed that the time was right for a small working conference at which researchers would exchange information about their current ideas on theoretical approaches, mathematical techniques, and computer processing. It was hoped to hold this conference during the fall of 1967 at The University of Kansas to take advantage of Dr. Peter Sneath's presence there during the fall semester. It is proposed to keep this conference small (less than twenty persons) and to avoid formal talks entirely. We may appoint discussion leaders to ensure roughly equitable coverage for various topics. Also, the conference should be restricted to actual workers in NT and while there is likely to be plenty internecine argumentation, we hope to sidestep at this meeting the by-now traditional disputes between advocates of conventional taxonomy and those of numerical taxonomy.

Regrettably, we have no funds for such a meeting and participants would have to find their own travel funds. For those without grant support, we shall try to arrange inexpensive meals and housing. So far, the following have indicated that they are likely to participate in the conference:

Theodore J. Crovello, University of Notre Dame
Paul R. Ehrlich, Stanford University
George F. Estabrook, University of Colorado
James S. Farris, University of Michigan
Peter H. A. Sneath, Leicester University
F. James Rohlf, The University of Kansas
Robert R. Sokal, The University of Kansas

Could you please fill out the enclosed form and return it to me without delay to enable us to plan further for the conference?

Bob

Robert R. Sokal
Professor of Statistical Biology

Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

19 September 1967

TENTATIVE SCHEDULE FOR CONFERENCE

Sunday, 12 November	8:00 p.m.	Mixer at home of F. James Rohlf.
Monday, 13 November	8:30 a.m.	Registration in front of Cottonwood Room at the Kansas Union. (All meetings to be held in Cottonwood Room.)
	9:00 a.m.	Address of welcome by University Provost.
	9:10 a.m. to 12:00	General theory of numerical taxonomy. Discussion leader: P. H. A. Sneath
	1:30 p.m. to 5:00 p.m.	Scaling and coding characters, similarity coefficients. Discussion leader: T. J. Crovello
	6:00 p.m.	Conference dinner, Centennial Room, Kansas Union.
	8:00 p.m. to ?	Informal discussion in Centennial Room.
Tuesday, 14 November	9:00 a.m. to 12:00	Representation of taxonomic structure, criteria of optimality. Discussion leader: Jerry Rubin
	1:30 p.m. to 5:00 p.m.	Numerical cladistics, information statistics and taxonomic keys. Discussion leader: D. J. Rogers

It is our intention to spend approximately half the time in informal contributions of no more than ten-minute length by various members of the audience addressed to the general topic under discussion. At the middle of each session there will be a break for coffee during which time informal exchanges of opinion can take place. In the final hour of each session, discussions from the floor covering the topics will take place. The discussion leaders will be expected to contact potential contributors to discussions in advance from the appended list of participants.

If you have any suggestions for changing the format of the meeting or the topics to be discussed, please let us know at the earliest possible moment.

INFORMATION ON TRAVEL AND ACCOMMODATIONS

Travel:

Lawrence is 36 miles from Kansas City. Lawrence is served by Union Pacific, Rock Island and Santa Fe trains, and by bus. The Kansas City Airport is almost in downtown Kansas City and the two bus terminals are only a short taxi or limousine ride away. If you let us know your arrival time at the airport, we shall try to send a microbus to Kansas City to pick up as many of you as is convenient in one trip. If your travel schedule is such that we can meet you by bus, we shall inform you.

Accommodations:

ELDRIDGE HOTEL
Seventh and Massachusetts Streets

Singles: $7.50

Downtown across the street from the inter-urban bus station. Also convenient to city bus to KU campus.

HOLIDAY INN
23rd and Iowa Streets

Singles: $8.25 and $9.25

Intersection of US 59 and State Highway 10. No public transportation and is at edge of town. Must get there and from there to campus by private car or taxi.

WESTVIEW MOTEL
1313 West Sixth Street

Singles: $6.18

On US 40. No public transportation. Must get there and from there to campus by private car or taxi.

Food:

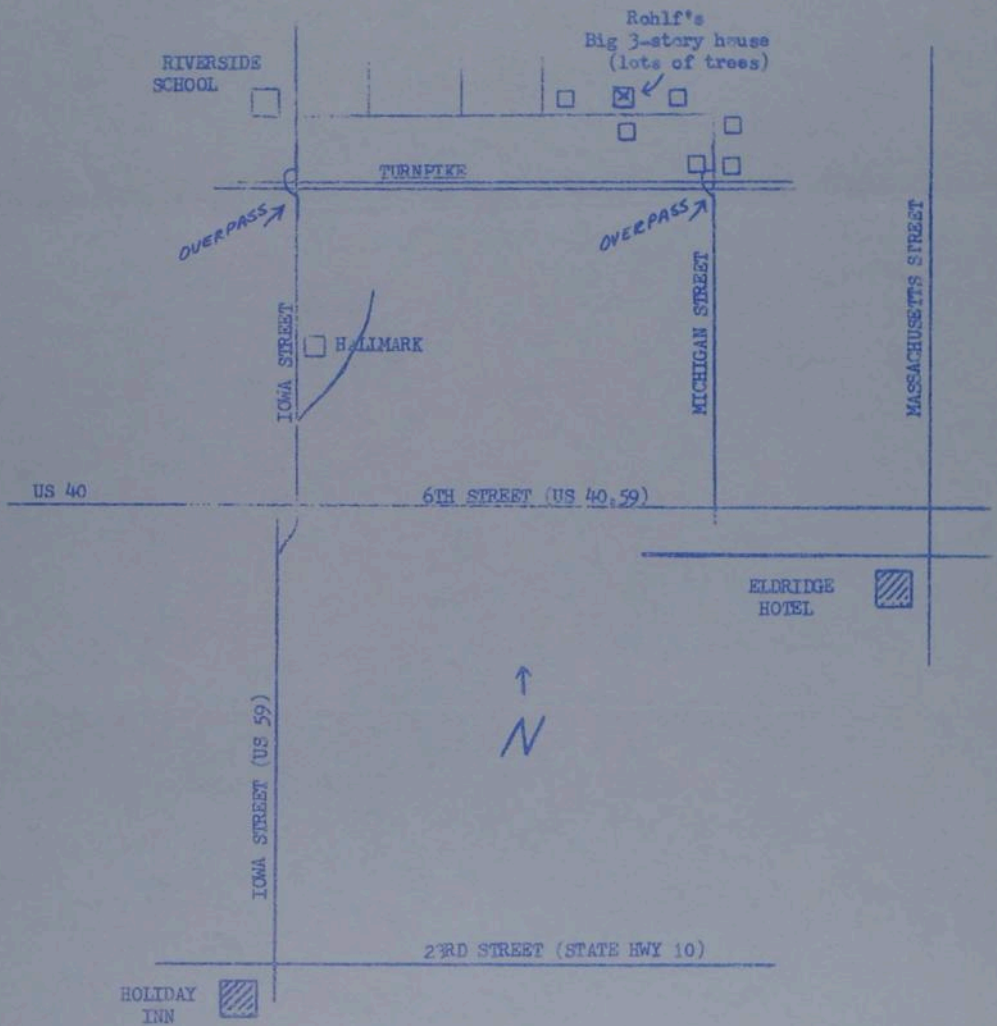
Breakfast may be obtained at the Eldridge Hotel and Holiday Inn or at the Union. We plan to eat lunch informally at the Union. A conference dinner has been scheduled for Monday night.

To Participants of the Conference on Numerical Taxonomy:

The response to our first circular has been overwhelmingly favorable. Nineteen workers in the field have indicated that they will attend. It will be a truly international conference with representatives from England, Canada, Japan, the United States, and possibly Australia. We may not succeed in keeping the conference as small as we had hoped. Including the University of Kansas representatives there will be over 30 persons. Still we are hoping to have the meeting as informal as is possible.

~~The majority preferred~~ Monday and Tuesday, November 13 and 14, 1967, ~~for the meeting and these dates have now been fixed.~~ The meeting will be opened by a mixer on Sunday night at 8:00 p.m. at ~~the home of F. J. Rohlf~~ Thurs Mt Shawnee Club House (address and instructions on getting there, enclosed). We would expect most participants to arrive by Sunday night. The sessions will be at the ~~Cottonwood~~ 156 Room in the Union building from 9:00 a.m. - 12:00 m. and from 1:30 p.m. - 5:00 p.m. on ~~Monday~~ Wed and ~~Tuesday~~ Thurs. A conference dinner will be held ~~Monday~~ Wed night in the Centennial Room of the Union. Please study the enclosed travel advisory sheet and fill out and return a reservation form so that we can make appropriate room reservations for you.

The mixer will be held on Sunday, 12 November at 8:00 p.m. at the home of F. J. Rohlf (Route 1, Box 278). This is just beyond the city limits and can be reached by car or by taxi as follows:



The local participants will try to provide transportation to and from the affair. Cars will leave the Eldridge Hotel and Holiday Inn at 8:00 p.m. on Sunday night. Please make it clear if you plan to be picked up.

Instructions for Driving to Lawrence

From Airport, drive South (toward Kansas City) about $\frac{1}{4}$ mile.

After you cross the toll-bridge, turn right at traffic light, bear left immediately for a feeder lane that gets you on the Intercity Viaduct (Interstate 70 going west).

Bear left on viaduct for feeder lane to Kansas Turnpike (Interstate 70 going west).

1. Holiday Inn passengers only:

   Use West Lawrence Exit (second exit).
   Follow exit road straight south. It passes under a viaduct and feeds into a four-lane highway going south (Iowa Street, also US 59). The Holiday Inn is at 23rd Street about two miles south.

2. Eldridge Hotel and Westview Motel passengers:

   Use East Lawrence Exit (first exit).
   Follow exit road 100 yards to highway. Turn left (south) and drive into town over Kansas River Bridge. Continue straight into Massachusetts Street. The Eldridge Hotel is on this street, one block down on the right. To go to the Westview Motel, turn right (west) at the bridge and go 8-10 blocks west on Sixth Street (also US 59).

   If you wish to go to the Holiday Inn via this route, continue west until you get to the highway intersection with Iowa Street where US 59 turns south. Follow that and go about two miles to 23rd Street. The Holiday Inn is at the corner.

BUS AND TRAIN SCHEDULES TO AND FROM KANSAS CITY AND LAWRENCE

BUS - 1021 McGee (Continental Trailways)*
12th & Holmes (Greyhound)**

Leaves Kansas City at: (Sundays)	Leaves Lawrence at: (Weekdays)
12:55 p.m.**	9:45 a.m.
1:45 p.m.*	10:40 a.m.
2:30 p.m.*	12:15 p.m.
4:45 p.m.*	1:55 p.m.
5:10 p.m.*	2:40 p.m.
5:15 p.m.**	4:10 p.m.
5:45 p.m.**	5:10 p.m.
6:40 p.m.**	5:36 p.m.
9:15 p.m.*	7:55 p.m.
10:30 p.m.**	8:10 p.m.
	9:40 p.m.
	10:40 p.m.

UNION PACIFIC - ROCK ISLAND TRAINS

Leaves Kansas City at:	Leaves Lawrence at:
7:30 a.m.	9:13 a.m.
8:00 p.m.	5:46 p.m.
11:00 p.m.	10:01 p.m.

SANTA FE TRAIN

Leaves Kansas City at:	Leaves Lawrence at:
5:00 p.m.	4:50 a.m.
10:45 p.m.	11:00 a.m.
	9:25 p.m.

TENTATIVE LIST OF PERSONS PLANNING TO ATTEND THE CONFERENCE

From Outside:

G. H. Ball, Stanford Research Institute
A. S. Boughey, University of California, Irvine
T. J. Crovello, University of Notre Dame
D. C. Eades, University of Illinois
P. R. Ehrlich, Stanford University
G. F. Estabrook, University of Colorado
J. F. Farris, University of Michigan
H. P. Friedman, IBM Systems Research Institute, New York
D. D. W. Goodall, University of California, Irvine
M. P. Johnson, Kent State University
W. R. Lockhart, Iowa State University
H. Morishima, National Institute of Genetics, Japan
W. W. Moss, Academy of Natural Sciences, Philadelphia
L. Orloci, University of Western Ontario
C. Quadling, National Research Council, Ottawa
D. J. Rogers, University of Colorado
J. Rubin, IBM Scientific Center, New York
M. Sackin, Leicester University, England
P. H. A. Sneath, Leicester University, England

From the University of Kansas:

J. H. Camin
D. R. Fisher
R. Johnston
R. L. Kaesler
J. R. L. Kishpaugh
C. D. Michener
F. J. Rohlf
A. J. Rowell
G. R. Smith
R. R. Sokal
P. V. Wells
W. J. Wrenn

17 October 1967

Dr. Robert R. Sokal
Department of Entomology
The University of Kansas
Lawrence, Kansas 66044

Dear Bob:

I will be glad to serve as a discussion leader.

Looking forward to seeing you.

Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

THE UNIVERSITY OF KANSAS · LAWRENCE, KANSAS · 66044

DEPARTMENT OF ENTOMOLOGY · SNOW ENTOMOLOGICAL MUSEUM

12 October 1967

Dr. David J. Rogers
Department of Biological Sciences
University of Colorado
Boulder, Colorado

Dear Dave,

I am writing to you in connection with the forthcoming conference on numerical taxonomy, to ask you to serve as discussion leader for one of the sessions as indicated in the enclosed material.

It will be the function of the discussion leader to open with some introductory remarks and to call on several persons in the audience known to have new and interesting ideas on the subjects under discussion for a brief presentation of their views. This will require scanning the list of participants which is enclosed, and contacting these people before hand.

In addition to these duties, the customary chores of controlling the meeting making certain that no one person monopolizes the floor, etc., etc. would be involved.

Would you let me know right away if you are prepared to undertake this role? Much will depend on the efficient direction of the discussion and your help in this is earnestly solicited.

Best wishes.

Sincerely yours,

Bob

Robert R. Sokal
Professor of Statistical Biology

RRS:vcb
encl.

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DIVISION OF BIOLOGICAL SCIENCES
DEPARTMENT OF POPULATION AND
ENVIRONMENTAL BIOLOGY
IRVINE, CALIFORNIA 92664

October 3, 1967

Dr. David J. Rogers
University of Colorado
Boulder, Colorado 80302

Dear Dr. Rogers:

Thanks for your reply of the 27th September. Enclosed is the latest of our technical notes describing how we are constructing the data base for the computer identification key we are working at, funded by NIH. A similar technical note is presently being prepared on the search strategy, and we will have a job-shop version of the whole thing working very soon. Maybe I will have an opportunity when we all meet in Kansas to describe this program.

I will certainly be there for the meeting in November. Whether or not we can get Goodall there remains still to be determined. I look forward to hearing of your work at this time.

With Best Wishes.

Yours sincerely,

Arthur S. Boughey, Chairman

ASB:ed
Enclosure

17 October 1967

Dr. James S. Farris
Museumoof Zoology
University of Michigan
Ann Arbor, Michigan 48104

Dear

The gathering of "computerniks" for evolutionary systematics at Bob Sokal's place has been straightened out, as you probably know..

I am writing to ask if you would be prepared to say a few informal words about numerical procedures and studies in evolution. Apparently nothing fancy in the way of preparation is required, but this is to forewarn you that during the last session I may ask you to make appropriate noises. I hope you will be prepared to do so; if not you don't even need to say "No" until the meeting.

Looking forward to seeing you again.

/Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

17 October 1967

Dr. F. James Rohlf,
Department of Entomology
University of Kansas
Lawrence, Kansas 66044

Dear Jim,

Please be prepared to say something about information retrieval on Tuesday afternoon (14 November) when I am discussion leader at the Numerical Taxonomy Conference.

Looking forward to seeing you.

Sincerely,

David J. Rogers
Professor of Biology

DJR:gm

THE UNIVERSITY OF KANSAS · LAWRENCE, KANSAS · 66044

DEPARTMENT OF ENTOMOLOGY · SNOW ENTOMOLOGICAL MUSEUM

October 31, 1967

Dr. David Rogers
Department of Biology
University of Colorado
Boulder, Colorado 80302

Dear David:

I will be prepared to say something about information retrieval on Tuesday afternoon (14 November) at the Numerical Taxonomy Conference.

Regards,

F. James Rohlf
Associate Professor of
Statistical Biology

FJR:bjm

24 October 1967

Mr. Jerry Rubin
I.B.M. Center for Scientific Research
56th and 5th Avenue
New York, N. Y. 10022

Bear Jerry,

Thanks for asking me to participate in the session Taxonomic Structure etc. of the Kansas meeting this November. I intend to stimulate discussion concerning the desirability of optimizing criteria based on the information content of a classification. Let me know if this is suitable. I look forward to seeing you in Lawrence.

Very truly yours,

George F. Estabrook

GFE:gm

24 October 1967

Dr. Theodore J. Crovello
Asst. Professor and Curator of the Herbarium
Department of Biology, College of Science
Notre Dame University
Notre Dame, Indiana 46556

Dear Ted,

Thanks for inviting me to contribute to the discussions at the Kansas meeting. I would be glad to say a few things. I will confine my prepared statement to literally a few words. The publications, Taxon and BioScience, that you mention, I would rather not mention formally. However, a very interesting idea concerning the coding of characters was advanced here and I intend to present this to generate discussion.

I look forward to seeing you in Lawrence.

Very truly yours,

George F. Estabrook

GFE"gm

31 January 1968

TO: Participants of the Numerical Taxonomy Conference in Lawrence

Dear Colleagues:

Enclosed with this letter you will find a list of participants of the conference and a preprint of Peter Sneath's summary of the proceedings. It will be published in the March issue of Systematic Zoology.

Also enclosed is a sheet giving the code numbers of some of the more successful pictures taken by Peter Neely. Some of them are very good and he has volunteered to send you copies at the following prices: 8 x 10 prints, $2.00 each; 5 x 7 prints, $1.00 each; 3 x 5 prints, $.50 each, plus an overall charge of $.50 for mailer and postage. You can also purchase contact proof sheets from him and then specify your own choices not quite so blindly. You may write him c/o Section of Biostatistics, Presbyterian St. Luke's Hospital, 1753 West Congress Parkway, Chicago, Illinois 60612.

I hope you enjoyed the Conference as much as those of us at Lawrence enjoyed arranging it. We feel we profited greatly and hope you did, too. We look forward with much eagerness and anticipation to our next such conference in Colorado.

Best wishes.

Sincerely,

Robert R. Sokal

Robert R. Sokal
Professor of Statistical Biology

RRS:cm

Enclosures

PHOTOGRAPH LIST

Roll	No.	Description
319	9	WELCOME NUMERICAL TAXONOMISTS sign at Holiday Inn.
319	20	During the lecture (Kaesler, Morishima, Kishpaugh, Rowell, Johnson, Sackin, Sokal).
320		At the mixer--0 = Ehrlich, Camin, Johnson; 1 = Rogers Friedman, Rowell; 2 = Michener, Sokal; 3 = Rogers, Freidman; 4 = Wrenn, Orloci, Eades, Kishpaugh; 9 = Doyle; 10 = Lockhart, Sneath; 11 = Sackin; 14-15 = Fisher, Sokal, Morishima; 16 = Boughey; 17 = Wells, Boughey; 18 = Wells, Boughey; 19 = Johnston; 20 = Michener; 21 = Merriam, Mrs. Rohlf; 24 = Rogers; 25 = Crovello; 26 = Lockhart; 27 = Ball; 28 = Goodall; 29 = Dale; 30 = Wells; 31 = Farris; 32 = Estabrook, Ball, Rogers; 33 = Ball, Friedman; 34 = Johnson, Rohlf, Michener; 35 = Rowen.
321		Group Pictures
	1	Before assembly.
	2	Assembled.
	3	Assembled.
	4	Rohlf, Sneath, Sokal (the sponsors).
	5	Rohlf, Sneath, Sokal (the sponsors).
	6	The session chairmen (Sneath, Goodall, Crovello, Rogers).
	7	The session chairmen (Sneath, Goodall, Crovello, Rogers) laughing more heartily.
	8	Ball, Sokal in foreground; Rowen, Sackin, Johnston, Rowell, Sneath, Goodall, Rogers, Crovello in background.

PREPRINT OF P. H. A. SNEATH'S REVIEW OF THE CONFERENCE (TO APPEAR IN THE MARCH, 1968 ISSUE OF SYSTEMATIC ZOOLOGY).

International Conference on Numerical Taxonomy

Lawrence, November 13th and 14th, 1967

A Conference on Numerical Taxonomy was held at the University of Kansas, Lawrence, on November 13th and 14th, 1967, attended by 35 participants representing nine universities in the U.S.A. and with members from Australia, Britain, Canada, and Japan. There were no formal contributions, and the sessions were opened by a few remarks from discussion leaders, followed by general discussion. Four main areas were chosen: (1) general theory of numerical taxonomy; (2) similarity coefficients and scaling and coding of characters; (3) representation of taxonomic structure, including criteria for optimality; and (4) taxonomic keys and numerical cladistics. It would not be feasible to summarize the numerous individual contributions to the discussions. This report therefore simply records the principal topics and the general conclusions on each.

As might be expected, the first session, on theory, covered the widest ground. The early part consisted of a discussion on the aims of numerical taxonomy, both now and in the future. Some members of the Conference felt that numerical taxonomy should not be directed toward what classical taxonomists have been doing over the years--a general map of organic diversity is available already from their labours--it should rather be directed toward new problems in evolutionary and ecological studies. However, it was pointed out that microbiologists are using numerical taxonomy very actively for classical purposes, because they do not have even a tolerably good general map of microbial diversity. The same must be true of many groups of organisms outside the best known ones, and on reflection one notes that the main phenetic relationships of animal phyla, orders of flowering plants and classes of thallophytes are extremely uncertain, to take only three examples at random. It was noted, however, that such pragmatic interests as those of microbiologists were not likely to give rise to many innovations in methods or applications.

The participants showed great interest in new applications for the methods of numerical taxonomy. For example, the usual measure of diversity of ecological associations take no account of the phenetic differences between the organisms of the association. It is clearly illogical to consider an association of two species of oak to be as diverse as an association composed of one species of oak and one species of conifer. Again, the disagreements between different numerical taxonomies could themselves open up new fields (most advances stem from unexplained discrepancies in current theories), and in particular the explanation of

incongruence between adult and larval resemblances was mentioned. Other applications included the study of clusters of characters that are empirically associated with certain biological functions (and which might also be causally connected); measures of diversification of ecological niches (one might argue that we only recognize a niche by the phenetics of the organisms that inhabit it); and the phenetics of growth of individuals.

The effect of the environment upon the organism and the plasticity of the phenotype could also be studied by these methods. Characters that are affected by the environment are here of special interest though a nuisance for taxonomy. One might even add environmental variables to the list of characters. Some examples were mentioned where phenetic studies had led to new interpretations in epidemiology, where unsuspected identities and subtle, previously unrecognized, phenetic subgroups were found to relate to the hosts of pathogenic microorganisms. In addition, numerical taxonomy is highly relevant to psychological theories of perception and pattern recognition, and will no doubt be extensively used in these fields.

Several members of the Conference said that it was difficult to persuade ecologists and others to entertain any new ideas on the lines mentioned above. The conference hoped that this point would be recorded in any report, and it is therefore duly noted here. It is not only taxonomy that has citadels of conservatism, it seems!

A second major topic was whether there was any general parametric measure of overall resemblance. It was clear that since there are many alternative ways of measuring similarity, the answer to the question as it stands above must be "no," or more precisely, such a question has no clear meaning until there is agreement on a specific similarity measure. This applies to all kinds of relationships, phenetic, phyletic, or genetic, because in every case the way of measuring relationship would need to be exactly specified even if all the facts about the organisms were known. However, given agreement upon how to measure the relationship, two further points aroused considerable discussion.

First, was there any parametric value that would be obtained if one could sample all the characters of the organism? It was generally felt that this question was very similar to the last. If one could agree precisely what was to be considered as a character there would in theory be a unique resemblance value if one knew all these characters. One cannot of course do very much about answering this question in practice until the complete genetic coding of some organisms is known. Even then it would be no easy task to relate these, and the unique resemblance values, to the phenotypes as measured in more conventional ways. This question in its broader aspects must therefore be left open for two reasons: we do not yet know enough about defining characters are relating them to the genome; and we do not yet know the complete genome of any organism.

The second question was whether one could in practice, with the techniques of the forseeable future, obtain a sufficient approximation to a parametric resemblance value. It was of course clearly realized that this sufficient approximation would depend partly on the taxonomic rank of the organisms compared, and partly on the way in which the samples of characters were chosen. At high ranks the congruence would probably be better than at low ones. Also, character sets chosen in a manner as near to random, or haphazard, as possible would be likely to give better congruence than those chosen from different organs or life stages. Despite some theoretical arguments for and against, based on both statistical and genetic grounds, it appeared that we do not yet have sufficient information to answer this question. We have as yet no experience with increasing the number of characters to the very large numbers indeed that are required to explore this problem, and we do not know enough about biological variation to discuss what degree of incongruence is due to biological factors rather than statistical sampling error.

The second session, on similarity coefficients and scaling and coding of characters is less easy to summarize. A great many points were raised relating to the different ways of handling characters, and the different underlying assumptions on what was most relevant to taxonomy.

A major topic was whether there were advantages in giving greater weight to agreements between the rarer character states, and several methods of doing this were presented. Such measures are primarily intended to facilitate discrimination between the OTU's. In a sense they measure the distances between OTU's in what might be rather loosely called "ease of discrimination units." The views expressed reflected individual opinions on whether this is generally desirable. Would the systematist, for example, wish to discard the information that two birds were very similar but very different from a mammal by using a resemblance coefficient that in some circumstances perhaps spaced them into approximately an equilateral triangle? This would make them about equally easy to distinguish. Many taxonomists think largely in terms of ready identification and discrumination, and it may be that practical needs in this respect are of major importance to many. Other workers are more interested in biological relationships of other kinds, and may therefore prefer the more usual phenetic coefficients. For example, a study of whether morphological resemblance is congruent with ease of hybridization might lose much of its point if the resemblances are adjusted so that hybrids and parents are spaced as nearly equidistantly as possible.

There was also discussion of various non-metric coefficients, but it cannot be said that their advantages were very clearly understood by the Conference. The sum of average absolute character differences was considered in relation to evolutionary phenomena, because it may be a better representation of evolution by successive selection of mutations than that given by other coefficients. This measure, however, is not invariant under rotation of the character hyperspace, unlike the Euclidean distance, and this requires further study.

There was also some discussion of primary and secondary characters, the appropriate scoring when organs are missing, and the degree of variation within species relative to the gaps between them

In the third session the representation of taxonomic structure was considered at some length. A main interest was the sort of criterion that would test the adequacy with which a phenogram represents the matrix of resemblances between OTU's. The commonest criterion at present is the cophenetic correlation coefficient. It was noted that this has certain drawbacks, but although various alternatives were suggested, most of these would not be applicable to all clustering methods. Cophenetic correlations have the advantages of being invariant to linear scaling and being applicable to any clustering method; they are sensitive however to the composition of the sample of OTU's, but so are other suggested alternatives. Indeed the discussion showed that numerical taxonomists have only just begun to look seriously at the sorts of taxonomic structures that are needed, and the appropriate tests of optimality. It was noted that the sum of squared differences between the corresponding pairs of values (one from the resemblance matrix, one from the phenogram), which is related to the cophenetic correlation coefficient, has some interesting properties. This quantity gives a curve of characteristic shape as the number of clusters in a phenogram is increased. Such curves can be partitioned into components reflecting the contributions to the lack of fit given by different characters.

New methods for clustering included several based on graph theory, a discipline of growing interest. One can minimize in various ways the length of the edges in graphs and networks. The development of concepts of "neighbors" was a particularly interesting new field. Some of these methods would make heavy demands on computing time, but this did not perhaps receive the attention it deserved. It was notable, too, that while various criteria for clustering were proposed, there was less consideration of their relative values for practical work. The Conference evidently had no very clear feeling of what purposes were in mind. It appeared important to the participants that more attention should be given to the properties of clusters that seem most relevant to biology, whether, for example, hyperspheroidal or elongated clusters are desirable, and for which applications. Suggestions were made for selectively finding elongated clusters, and it was noted that although the character space was of high dimensionality, one might perhaps find individual clusters which could be represented well in only a few dimensions.

Several techniques were described for preserving the maximum amount of information in a classification. The aim here is to divide the set of OTU's in such a way that the resulting subsets retain the greatest quantity of useful information. What constitutes the most useful information is still subject to question, but the general concept was close to Gilmour's "natural" groups; that is, the groups

should enable one to make the maximum number of propositions about the attributes of their members. It was noted, however, that these methods are likely to be rather insensitive to the misplacement of a few OTU's. The entry into a cluster of a single highly aberrant OTU may not decrease the information content sufficiently to ensure that it is rejected and placed elsewhere. These methods may thus perhaps be unduly sensitive to vagaries of sampling (particularly of sampling OTU's).

The final session was on two unrelated topics, identification and cladistics. Some recent work on computer diagnostic keys was described. A broad but indistinct division can be made into identification methods which are predominantly sequential and those which operate on numerous characters simultaneously in the hope of providing a unique identification in one step. The first are commonly constructed so that the user enters a few characters of his unknown specimen at first, and finds out the most likely taxa to which it belongs. He then examines other characters to narrow the identification further, aided by the computer, which suggests the next characters to examine. This is very much like a familiar printed key, but stored in the computer. The second method compares the unknown with all the reference taxa by computing something analogous to a resemblance coefficient, in the hopes that this will show unambiguously which is the correct identification. With both strategies one may obtain some estimate of the probability that the identification is accurate, and in practice it is often convenient to combine some features of each strategy. Boolean operations may be potentially useful in this field.

Curiously, discriminant functions were scarcely discussed, although the participants were quite familiar with them. This may have been because discriminant functions are not very practicable for identification among large numbers of taxa that are reasonably distinct: key characters, suitably chosen, seem more useful. Certainly there was little discussion on discrimination with poorly separated taxa. There was some mention of "learning methods," i.e., those in which the unknowns are allocated to taxa whose descriptors are updated with the information from these new members. It was not clear how far these methods (principally developed in the fields of pattern recognition and medical diagnosis) would perform in taxonomy, but there was a feeling that they might break down unless the taxa were sharply distinct from one another.

The Conference also noted that there was a need for a computer method for generating a printed sequential key from any given body of data, and this deserves further study. Clearly, one would need some additional information (such as which characters are easiest to determine and least likely to be missing) for a practical system.

Some of the most lively discussion was on numerical cladistics. Much attention was given to how one could estimate the most probable cladistic tree, centering around the minimally connected graphs known

as Prim networks. Such a network is the minimum pathway that is needed to connect all the OTU's. It does not imply what is the degree of relationship between OTU's that are separated by several links, because the same network can represent an elongated cluster or a horseshoe-shaped cluster. It has properties that make it worth further study, and it may be noted that it is similar to the dendrite method of the Polish school of "Wroclaw taxonomy."

It was by no means clear what prior assumptions about evolution are made if one uses Prim networks to estimate probable cladistic relationships. Cladistic relationship requires the ancestor-descendant relations to be specified, and there is no obvious way these are related to the networks. Another problem is how one is to estimate some sort of confidence limits of cladograms. The paleontologists present were pessimistic on this; they inclined to the view that the ambiguities were likely to be large. One point they made was that a large number of characters was needed to achieve significant results, probably two or three times as many as the number of OTU's.

Conclusions. It was certainly refreshing to attend a conference on numerical taxonomy at which the best way to perform it was discussed, rather than whether it was permissible at all. The active work now going on in the institutions of the participants, and the high proportion of young scientists present, indicates that the coming years will be exciting ones for systematics.

The early days of numerical taxonomy were much taken up with the question of whether such methods could produce reasonably satisfactory results. Today there is general agreement that they can. But increasing experience has brought a realization that they can produce many classifications, all reasonable, all fairly satisfactory, but different in small ways. Systematists must now give much closer attention to exactly what qualities are needed of the classifications. No doubt the logical and mathematical methods will become more sophisticated and every aspect of systematics will become increasingly numerical, but without this attention to purpose these advances will be of little profit.

The future should also be interesting in a second and novel way. Numerical taxonomy will more and more be used heuristically. That is, it will serve to increase knowledge not just by rearranging organisms into more satisfactory taxa, but by posing and testing hypotheses that could not be made or tested in any other way. The time is coming when numerical taxonomists may set the problems to other biologists, instead of simply attempting to solve problems that other biologists set them. Already this is happening in ecology, and in a widening field of applications to other disciplines. Such studies, too, will be of the greatest significance in understanding the psychology of perception. Indeed these widening vistas may lead us in the future to think more of numerical classification, rather than the narrower applications to systematic biology that is implied by the terms numerical taxonomy or taxometrics.

As a postscript it was noticed that it was particularly significant that the photograph of the conference was taken on the steps of the University Natural History Museum, within whose walls one of the very first papers on numerical taxonomy was given over a decade ago.