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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.

JUN 17 1976

Rita
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DATE RECEIVED:

Abbott, Lois
 April, Jay
 Bailey, Mark
 Bishop, Judy
 Borsuk, Ronnie
 Bryant, Peter
 Emery, Don
 Fellay, Helga
 Gruidel, Ed
 Hanley, Jim
 Herish, Gil
 Kalin, Nancy
 Kaltenhauser, J.
 McArthur, Greg
 Rawal, Kanti
 Rogers, Connie
 Rogers, Dave
 Schiffman, R.
 Shafton, Allan
 Sim, Bev
 Snow, Jim
 Snyder, Max
 von Borstell, G.
 Weinert, J.
 Welner, Steve

Initial

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Filing:

Original

Pedro Garindo

Copies:

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Organization

COMMENTS:

JUN 17 1976

UNIVERSITY OF COLORADO
Ketchum 306
BOULDER, COLORADO 80302

Master of Basic Science Program

15 June 1976

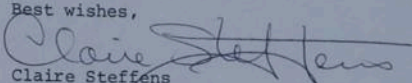
Dr. Jay April
Taximetrics Laboratory
1229 University Avenue
Boulder Campus

Dear Dr. April,

Thank you very much for your help by serving
as reader for the paper by our student Pedro
Garrido.

Your expertise and help to our program enables
it to continue and makes participation in
the program more meaningful to our students.

Best wishes,


Claire Steffens
Administrative Assistant

JUN 17 1976

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Ketchum 306E
BOULDER, COLORADO 80302

Master of Basic Science Program

15 June 1976

Dr. David J. Rogers
Hale 114
EPO Biology

Dear Dr. Rogers,

Thank you very much for your help by serving as reader and advisor for the paper by our student Pedro Garrido.

Your expertise and help to our program enables it to continue and makes participation in the program more meaningful to our students.

Best wishes,


Claire Steffens
Administrative Assistant

Barcelona, 11th., March, 76

Dr. David J. Rogers
Taximetrics Lab.
Boulder

Dear Dr. Rogers:

Thank you for your letter of January 7th.
I have finished the paper and I have sent two copies
to Ms. Claire Steffens on The Master of Basic Science
Program. I hope you will not be very bored by reading
the paper.

Sincerely

Yves Fauriol

January 7, 1975

Mr. Pedro Garido
Via Layetana 163
Barcelona 9
Spain

Dear Pedro:

Forgive me for the delay in answering your letter of November 15th.
Your outline looks fine. Just pursue it and it will be satisfactory.

Best wishes to you for the New Year!

Sincerely,

David J. Rogers

DJR:hf

Barcelona, November 15th, 1975

Dr. D. J. Rogers
Taximetries Lab.
University of Colorado
Boulder

Dear Dr. Rogers:

As we agreed in our last talk I send you an outline of the project I have to present as a paper for the Basic Science department.

I think that basically the paper could be a comparison of the different methods used normally in Taximetries, with comments about their utility, bounding, etc... The data will be the ones of Hippocrepis, because with them I ran all the programs in Boulder, Oeiras & Barcelona.

The parts of the project would be as follow:

- I.- Introduction and justification of the project.
- II.- Explanation of data and characters.
- III.- Programs used and a short description of them.
- IV.- Conclusions of the obtained results and errors.
- V.- Bibliography.

Please, let me know your opinion.

Sincerely yours

Pedro Gaudin

UNIVERSITY OF COLORADO
Ketchum 306E
BOULDER, COLORADO 80302

MAY 03 1976

Jay

Master of Basic Science Program

28 April 1976

Dr. Jay April
Taximetrics Laboratory
1229 University Avenue
Boulder Campus

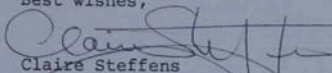
Dear Dr. April,

Thank you for your letter of 23 April indicating your acceptance of the paper by MBS candidate Pedro Garrido in lieu of the comprehensive examination.

Enclosed is an examination report form which when you have signed will indicate this acceptance to the Graduate School. Please return the form to this office.

Thank you for your help in reading this paper.

Best wishes,


Claire Steffens
Administrative Assistant

X6093

TO Claire Steffans, Ketchum 306E
FROM Judy Bishop, TB 72
SUBJECT Attached form for Pedro Garrido
DATE May 4, 1976

UNIVERSITY OF COLORADO

*Interdepartmental
Memorandum*

Per our telephone conversation, Dr. April is out of town until May 28.

Therefore, he will be unable to sign the attached form until then.

*Judy
Please
return to
Ketchum 306E
Judy*

ACTA PHYTOTAXONOMICA BARCINONENSIA. — VOL. 13

UTILIZACIÓN DE UN MÉTODO DE ORDENACIÓN
PARA DESCRIBIR Y COMPARAR ESQUEMAS TAXONÓMICOS:
APLICACIÓN A LAS ESPECIES DEL GÉNERO HIPPOCREPIS

POR

PEDRO GARRIDO

I.N.E.M. Emperador Carlos. Barcelona

Y

ANTONIO ESCARRÉ

Departamento de Biología, C.E.U. Alicante

DEPARTAMENTO DE BOTÁNICA — FACULTAD DE CIENCIAS
UNIVERSIDAD DE BARCELONA

1973

Application of numerical methods to the study of the genus *Hippocrepis* L.

(Summary of the works done until May 1974)

- I Utilization of the principal coordinate analysis of Gower and the Graph "clustering analysis".
- II Application of the Graph program to the study of data obtained from fruits.
- III Application of the Charanal program to the study of data obtained from fruits.

I Utilization of the principal coordinate analysis of Gower and the Graph "clustering analysis". (1)

These methods of ordination are applied here to interpret numerically and graphically the taxonomic opinion of the authors Ball and Bellot.

A character divides the objects under study into groups. All the objects of each group have the same character state. Ex.: Character: color of the flower. States: red, pink, white.

Once the character and character states are established, each one of the species (objects) can be defined by means of a sequence of states.

(1)

Gower, J.C. 1966. Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* 53, 325-28.

Gower, J.C. 1968. A general coefficient of similarity and some of its properties. *Roneo rothantsed Exp. Stat.* 16p.

Legendre, P. and D.J. Rogers. 1972. Characters and clustering in taxonomy: A synthesis of two taximetrics procedures. *Taxon* 21(5/6): 567-606. Nov. 72.

For the *Hippocrepis* genus the data (character and character states) have been taken from the keys for determination of species and from the species descriptions given for both authors. (2)

In the mentioned bibliography, the character states are seldom explicit. This have obliged me to establish them by myself. In other cases when describing an species, the author does not make any reference to a character he uses in describing another species. Further, for some characters the lack of data is such that I have had to put them aside from the study.

Besides the key for species determination and the description, the authors give relationships of this type: "Species 1, 2, 3, and 4, are very like each other" or "The most similar species to 5 is 6". As common among taxonomist, these sorts of relationships are given on the basis of their knowledge of the taxa; and these relationships can not be directly deduced from the characters they use in the keys and descriptions.

The more information a key has the most the degree of similarity among the species will show. The two methods used in this work give, starting from the characters of the descriptions and the keys, measurements of similarity between species. These measurements can be represented graphically. By making comparisons between these measurements and the taxonomic judgements of the authors, it is possible to evaluate the extent to which the author has put, in the key, all the information he possesses. Also it is possible to compare keys that use different characters. Finally, it is possible to deduce relationships between species or groups of species not mentioned by the author.

As I considered all the characters in the first programs to be of equal importance, the similarities and the schemes were different from the authors. This is because the authors do not consider all the characters as having the same weight. So, to fit the author's thought more, it was decided to use a sistem of weighting characters.

A very simple procedure to do that is to give weight 1 to a character, if the author does

(2)

Ball, P.W. 1968. *Hippocrepis* L. in *Flora Europaea* vol. 2, Cambridge University Press, Cambridge.

Bello, F. 1947. Revisión crítica de las especies del género *Hippocrepis* de la Península e islas Baleares. *Anal. Inst. Bot. Cavanilles* 7:197-334.

not use it in the identification key but uses it in the species description; weight 2, if the character is in the second half of the key; and weight 1 if the character is in the first half of the key. In the listing of characters, the states are specified, along with the weights, into brackets.

Program Gower (Data from Ball)

Qualitative characters:	Weight
1.- Flowers sessile/pedunculate-----	(3)
2.- Flowers solitary/umbel-----	(3)
3.- Plant annual/perennial-----	(3)
4.- Loment glabrous/hirsute-----	(2)
Multistate characters:	
5.- Sinus of the loment lunate/semicircular/horseshoe-shaped/orbicular----	(2)
6.- Claw of the standar about as long as the calyx/up twice as long as the calyx/more than twice as long as the calyx-----	(2)
Quantitative characters:	
7.- Length of the corole-----	(2)
8.- Width of the leaflets-----	(1)
9.- Number of leaflets per leaf-----	(1)
10.- Height of the plant-----	(1)
11.- Length of the leaflets-----	(1)
12.- Length of the loment-----	(1)

In fig.1 Bl. are shown the results of this program.

Program Gower (Data from Bellot)

Qualitative characters:	
1.- Plant annual/perennial-----	(3)
2.- Flowers solitaires/umbel-----	(3)
3.- Seeds light color/dark-----	(1)
Multistate characters:	
4.- Papillae in the seed protuberance very short or no one/normal/normal and also in the rest of the loment/very long all over the loment-----	(3)
5.- Flowers sessile/pedunculate shorter than the leaf/equal or up twice the leaf/between twice and three times/between 3 times and 4 times/ between 4 times and 5 times-----	(2)
6.- Sinus of the loment lunate/semicircular/orbulate-----	(2)
7.- Loment straight/flexuous/curve-----	(1)

Fig. 1. Bt.

Fig. 1 Bt.

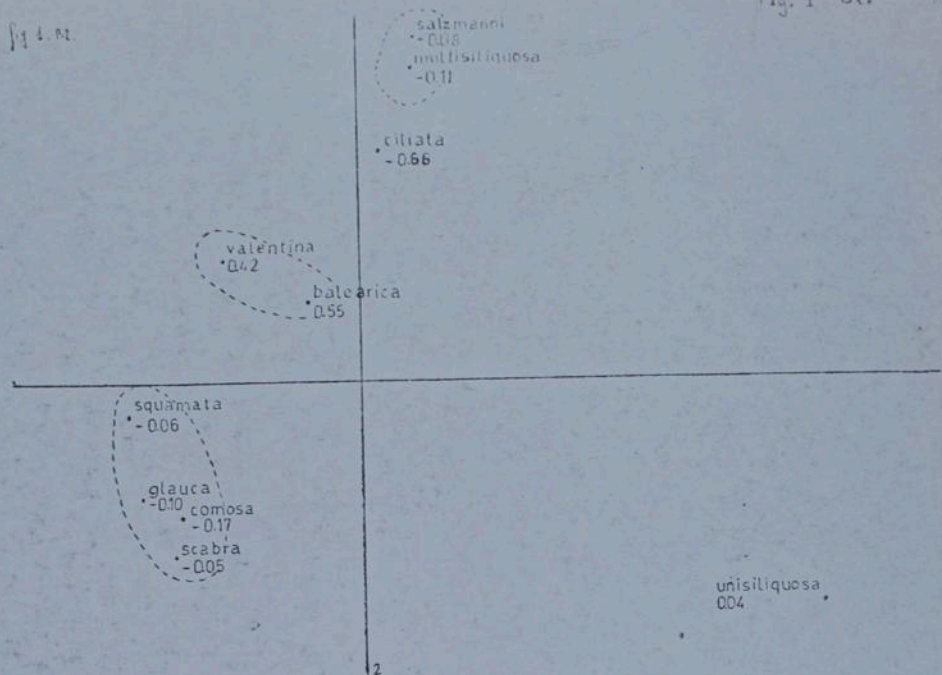
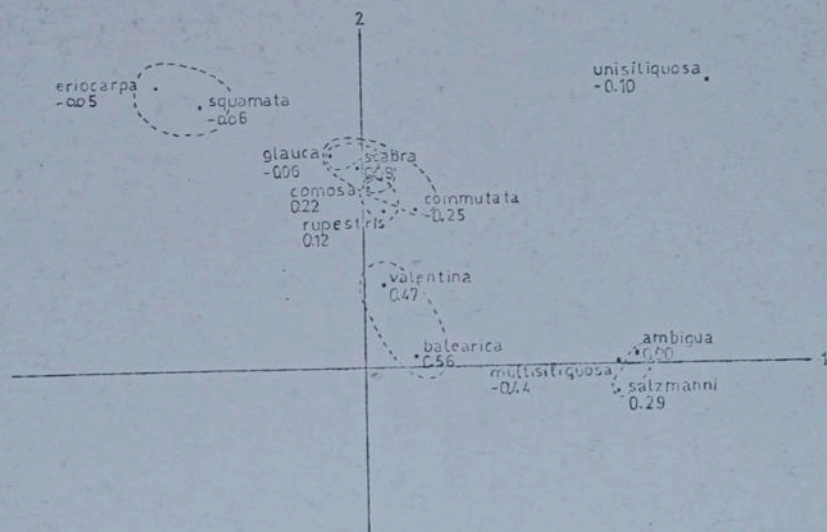


Fig. 2. Bt.

Fig. 2 Bt.



Quantitative characters:	Weight
8.- Number of segments per loment-----	(3)
9.- Size of the flowers-----	(2)
10.- Number of leaflets per leaf-----	(1)

In fig. 2 Bt. are shown the results of this program.

Comments on the results of the Gower programs

the results are in figures 1 Bl. and 2Bt. In them, the space of the principal vectors 1 and 2 is represented. Also, in each point the value of the third vector is given.

First of all, it is interesting to compare each figure with the relationships pointed out by the respective author, in order to appreciate the degree of coincidence.

Fig. 1 Bl. For Ball, *Hippocrepis* is: "a taxonomically difficult genus in which there are great differences of opinion in respect to the situation and relationships of most of the taxa, specially in *H. glauca*, *H. scabra*, *H. comosa*, and *H. squamata*". Further, he insists that: "*H. glauca*, *H. scabra*, and *H. comosa* are not easy to distinguish from each other. In the descriptions of *H. balearica* and *H. salzmanii*, he mentions their similarities to *H. valentina* and *H. multisiliquosa*, respectively.

By examining fig. 1 Bl. one can appreciate the coincidences because all the similarities signaled by the author correspond with proximities among the species (groups surrounded by the dotted line).

Fig. 2 Bt. In the review of the genus *Hippocrepis*, Bellot mentions even more similarities. So, among the annuals, he points out that: "*H. salzmanii* and *H. ambigua* have great similarities". Similarly, he refers to *H. valentina* and *H. balearica* and he continues: "among the perennials there are two, *H. eriocarpa* and *H. squamata*, with undoubtable similarities". Regarding *H. glauca*, he points out that some varieties of this species are like *H. comosa*. About *H. scabra*, he says that *H. commutata* is the most similar and then follows *H. comosa*. Also, some varieties of *H. scabra* are related to *H. glauca* var. *bourgaei*. Finally, although with some reservation, he considers *H. rupestris* to be a fissure form of *H. comosa*.

An examination of fig. 2 Bt. shows correspondences with the similarities signaled by Bellot in the cases of *H. ambigua*-*H. salzmanii*, *H. valentina*-*H. balearica*, and *H. eriocarpa*-*H. squamata*. Regarding to the group *H. glauca*-*H. comosa*-*H. rupestris*-*H. scabra*-*H. commutata*, the complex relationships described by Bellot are generally maintained, with the exception

of the excessive distance between *H. scabra* and *H. commutata*.

Also the applied method permits a comparison, through figure 1 and 2, of the criteria of both authors. One can see that they have very similar structure. In both cases, *H. multisiliquosa* is distinguished as a well defined species. The group *H. squamata*-*H. glauca*-*H. comosa*-*H. scabra* in figure 1 Bl. corresponds well with the wider group in figure 2 Bt., which also includes *H. eriocarpa*, *H. rupestris* and *H. commutata*. The position of the group *H. valentina*-*H. balearica* is practically the same in both figures.

At first glance, the major discrepancy seems to be between the group *H. salzmanii*-*H. multisiliquosa*-*H. ciliata* in fig. 1 Bl. and the group *H. multisiliquosa*-*H. ambigua*-*H. salzmanii* in fig. 2 Bt. In fig. 1 Bl. *H. ciliata* and in fig. 2 Bt. *H. multisiliquosa* are separate from the other two (note coordinates of the third axis). In this case what the method indicates is not a difference in taxonomic criteria but instead a different nomenclature, since *H. ciliata* Wild., in Ball, corresponds to *H. multisiliquosa* L. in Bellot, and *H. multisiliquosa* L. in Ball, corresponds to *H. ambigua* (Rouy) Bellot, in Bellot.

Program Graph (Data from Ball) = PROGRAMA COLO-5 Fl. Eu. (con cargos).

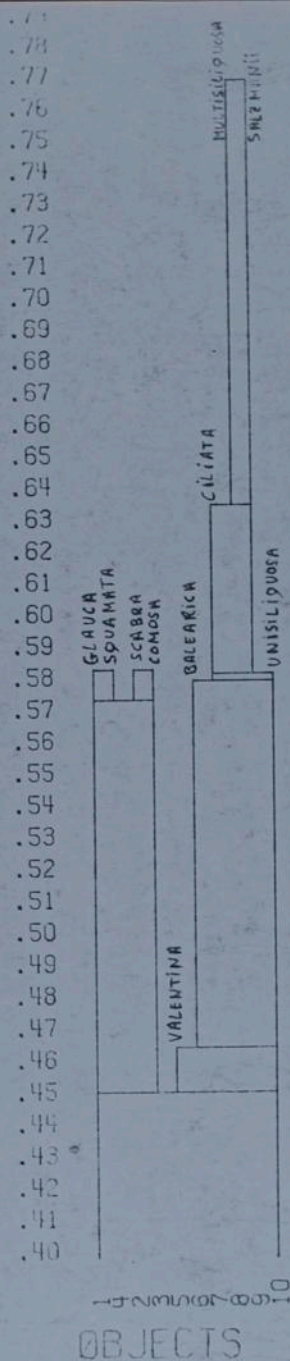
character:	type:	weight:
1.- Length of the peduncle -----	ordered -----	(3)
2.- Plant annual/perennial -----	normal -----	(3)
3.- Number of flowers per umbel -----	matrix -----	(3)
4.- Length of the corole -----	" -----	(2)
5.- Length of the papillae of the fruit -----	normal -----	(2)
6.- Color of the papillae -----	" -----	(2)
7.- Number of leaflets per leaf -----	matrix -----	(1)
8.- Shape of the leaflets -----	" -----	(1)
9.- Length of the leaflets -----	" -----	(1)
10.- Width of the leaflets -----	" -----	(1)
11.- Length of the loment -----	" -----	(1)
12.- Width of the loment -----	" -----	(1)
13.- Shape of the sinus of the loment -----	" -----	(2)
14.- Length of the claw of the standard -----	normal -----	(2)
15.- Height of the plant -----	matrix -----	(1)

The results of this program are in the figure whose title is : PROGRAMA COLO-5 GRAPH Fl. Eu. (con cargos).

EXS 74/01/28 0571D EST 2 FT

PROGRAMA CØLØ-5 GRAPH FL.EU. (CØN CARGAS)

C-VALUE



Program Graph (Data from Bellot) = PROGRAMA COLO-6 Bellot (con cargos).

character:	type	weight
1.- Plant annual/perennial-----	matrix -----	(3)
2.- Flowers solitaires/umbel-----	" -----	(3)
3.- Ratio peduncle/leaf-----	" -----	(2)
4.- Lenght of the papillae-----	" -----	(2)
5.- Colour of the papillae-----	" -----	(2)
6.- Color of the seed-----	" -----	(1)
7.- Position of the sinus-----	" -----	(2)
8.-Size of the flower-----	" -----	(2)
9.- Pubescence of the calyx-----	" -----	(1)
10.-Number of segments per loment-----	" -----	(3)
11.-Shape of the loment-----	" -----	(1)
12.-Shape of the sinus -----	" -----	(2)
13.-Number of leaflets per leaf-----	" -----	(1)

the results of this program are in the figure whose title is :PROGRAMA COLO-6 GRAPH BELLOT (con cargos).

Comments on the results of the Graph programs

Program Colo-5 Fl. Eu.

The group *H. glauca*-*H. squamata*-*H. scabra*-*H. comosa* from the figure coincides perfectly with the similarities indicated by Ball (see p.5). The group *H. ciliata*-*H. multisiliquosa*-*H. salzmanii* is well represented, when tough the high similarity index of .77 between *H. multisiliquosa* and *H. salzmanii* is somewhat surprising. The similarity between *H. balearica* and *H. valentina* is not reflected. As to *H. unisiliquosa*, a greater isolation was expected.

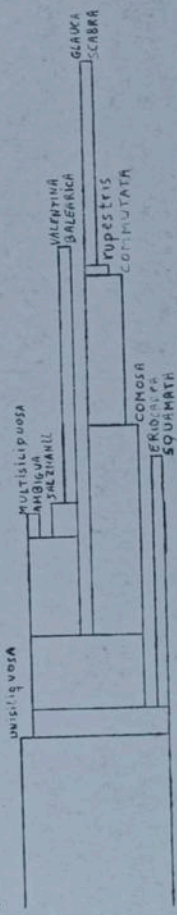
Program Colo-6 Bellot

The group *H. eriocarpa*-*H. squamata* on one hand and the group *H. valentina*-*H. balearica* on the other, are very well described in the figure. *H. unisiliquosa* is also well defined. The group *H. glauca*-*H. comosa*-*H. rupestris*-*H. scabra*-*H. commutata* is well defined, although the internal relationships are not exactly in accord with the ones given by Bellot (see p.5). Finally, it must be noted that the relation *H. multisiliquosa*-*H. salzmanii* pointed out by Bellot is not sufficiently emphasized in the figure.

PROGRAMA COLD-6 GRAPH BELLOT (CON CARGAS)

C-VALUE

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OBJECTS

Conclusions for Part I

Generally, both Gower's principal coordinate analysis and the Graph "clustering analysis" express in a good way the relationships given by the authors. However, there are some discrepancies between the two methods, especially the Graph method, and the judgements of similarity given by the authors. These discrepancies can be interpreted as the result of the incomplete information obtained from the keys and the descriptions. In any case, especially regarding the graph data, one must consider that the criteria used to establish the character states may be responsible for the distortion of the similarities in the figure.

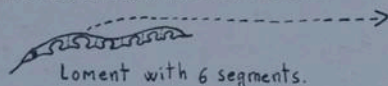
II Application of the Graph program to the study of data obtained from fruits.

Since during my stay at C.U. I have not had enough complete specimens, but have had an abundant number of fruits, I have attempted to study the fruits in detail.

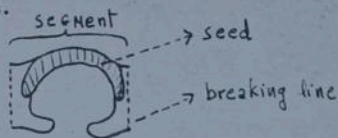
First of all, this study attempts to find the largest number of characters of the fruit with taxonomic utility. Second, it evaluates the possibility of identifying species from the characters of the fruit.

The first step consisted of establishing the characters.

- 1.-Number of segments of the loment.



Loment with 6 segments.



The number of segments of the loment is equal to the number of seeds. The fruit breaks naturally into segments along the "breaking line".

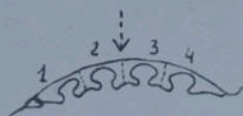
- 2.-Width of the loment in the "Breaking line".



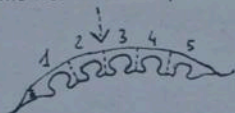
d = width of the loment in the "breaking line".

Only one breaking line is measured in each fruit.

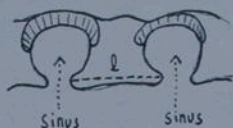
If the number of the segments of the fruit is even, one measures the central line:



If the number of segments of the fruit is uneven, one measures the breaking line anterior or to the central segment :



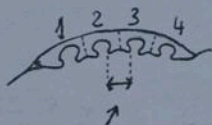
3.-Distance between the openings of the sinus.



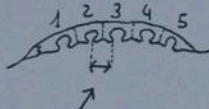
l = distance between the opening of the sinus.

Only one distance in each fruit is measured.

If the number of sinus is even, the distance between the two central sinus is measured:



If the number of sinus is uneven, the distance between the central sinus and the anterior one is measured:



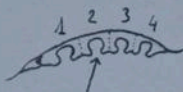
4.-Height of the sinus.



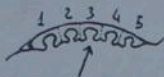
F = Height of the sinus.

Only one height measurement is taken.

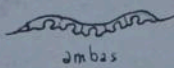
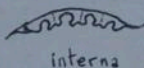
If the number of sinus is even, the height anterior to the central breaking line is measured:



If the number of sinus is uneven, the height of the central sinus is measured:



5.-Opening of the sinus in relation to the curvature of the loment.



6.-Pubescence of the loment.

It is the grade of pubescence of the fruit.

7.-Shape of the sinus.

Several character states have been established according to the shapes:



cerrado



aguja



u

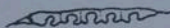


abierto

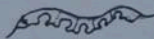
8.-Shape of the fruit.



curvo



recto



sinuoso

9.-Weight of the loment.

Each fruit has been considered as an O.T.U. In this study 128 fruits belonging to the species of the genus *Hippocrepis* according to Bellot have been considered.

Comments

The objective of this program has been to determine whether the groups were clustered according to the species to which they belong. Because of size limitations, it has been impossible to reproduce the graph, but I have included the Graph's comments and conclusions.

The variability of the fruits of the same species and the negligible difference between the means of the distribution of one character in two or more species results in the fact

that sometimes fruits of two different species have higher similarities than fruits of the same species.

So for $s = .99$ there are two groups a and b.

The group a is formed by 22 fruits: 10 of *H. multisiliquosa*, 8 of *H. commutata*, 4 of *H. scabra*, and 1 of *H. rupestris*.

The group b is formed by 15 fruits: 3 of *H. eriocarpa*, 3 of *H. squamata*, 3 of *H. comosa*, 2 of *H. rupestris*, 2 of *H. glauca*, 1 of *H. valentina* and 1 of *H. scabra*.

In conclusion, the use of the characters of the fruit only serve to differentiate very different species phenetically.

Nevertheless, I believe that if the means of the distribution of the characters by species have significant differences, then knowing the means for the characters of each species, would be possible to determine the species of fruit if we have a sufficient (statistically) number of fruits.

III Application of the Charanal program to the study of the characters of the fruit.

The Charanal program (Character analysis) is primarily used to study the correlation between characters. The program analyses the amount of information that two characters share. As the authors explain: "When a correlation is found, two possibilities exist: either is a valuable correlation between two characters, corresponding to a genetic correlation, in which case both characters should be kept, since good taxa are based in correlated characters; or the correlation is due to an undesired redundancy, as a consequence of the same structure being unintentionally described twice".

From the point of view of the characters used in this program the greatest danger was using redundant characters.

The Charanal program is also useful to calculate which character shares the most information with all the others. For this the SUMRAT and SAMRAT values are calculated. If SUMRAT is large, the character shares much information with the others and is useful for classification purposes.

Program Charanal(Data from seeds)

The same objects and the same characters have been used as in partII (see p.7-9)

Results and comments of the Charanal programs (Programa COLO-1)

The similarities between characters (only the four largest have been listed) are:

- .20094 between character 5 and 8 (Opening of the sinus...and Shape of the fruit)
- .19666 between character 6 and 7 (Pubescence of the loment and Shape of the sinus)
- .14019 between character 5 and 7 (Opening of the sinus...and Shape of the sinus)
- .13658 between character 2 and 6 (Width of the loment... and Pubescence,...)

SUMRAT :

- 1.83776 character 7 :Shape of sinus.
- 1.60310 character 3 :Distance between the openings of the sinus.
- 1.48184 character 6 :Pubescence of the loment.
- 1.42837 character 5 :Opening of the sinus in relation to the curvature of the loment.

SAMRAT:

- 1.74357 character 4 :Height of the sinus.
- 1.41936 character 7 :Shape of the sinus.
- 1.20606 character 2 :Width of the loment in the breaking line.
- 1.19757 character 6 :Pubescence of the loment

The similarities are small. No pair of characters are very or highly correlated. The highest similarity occurs between characters 5 and 8, and in this case probably a redundancy is reflected. The remaining similarities between pairs 6-7, 5-7, and 3-6, are probably instances of authentic correlation.

By observing SUMRAT and SAMRAT, one note that character 7 shares most information with all the others. At first glance, the high value of SAMRAT for character 4 is surprising, because it was known "a priori" that this was an inconsistent character. This can be explained because its entropy(=information) is the lowest of all. Because the way SAMRAT is calculated, its value must be high, and has no significance.

(Programa COLO-7)

In this program the same characters were used as in Program COLO-1 excluding characters number 4, 8, and 9. The number of objects has been reduced to 60 so that no object is in

void states for any character. The similarities are:

- .25089 Between Character 6 and 7 (Pubescence of the loment and Shape of sinus)
- .16912 between character 3 and 6 (Distance between.... and Pubescence of the loment)
- .16244 between character 5 and 7 (Opening of the sinus.... and Shape of the sinus)
- .15808 between character 3 and 7 (Distance between.... and Shape of sinus)

It is a pity that for no known reasons SUMRAT and SAMRAT have not been calculate by the computer.

Comments to Programa COLO-7 :

All the similarities, although not very high, can be considered instances of authentic correlation. The lack of terms SUMRAT and SAMRAT, prevents one of using the program as fruitfully as possible.

Comments on Part III

The character 7, Shape of the sinus, is the best in both programs.

The rest of the characters expressly cited in the previous comments also seem valid except for number 4, Height of sinus.

Except for the 5-~~3~~⁶⁻⁷ (redundant) and 4-~~4~~ (authentic correlation) the remainder are not correlated.

MASTER OF BASIC SCIENCE PROGRAM
Ketchum 306E
UNIVERSITY OF COLORADO
BOULDER, COLORADO 80302

8 March 1976

Dr. David T. Rogers
EPO Biology Department
Hale 114
Boulder Campus

Dear Dr. Rogers,

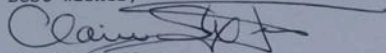
Enclosed you will find a paper by MBS student Pedro Garrido Lagunilla entitled "Evaluation of Some Numerical Techniques Using Biological Data". Thank you very much for your consideration of the paper. Also enclosed is a brochure describing the MBS program.

The paper or project prepared by a candidate is in lieu of the comprehensive examination. As such it must be of a master's level in quality and accuracy, need not be original, and is not a thesis. Because the MBS program has no faculty as such, students in the program rely on the expertise of readers who are members of the faculty in departments related to the subject areas with which their papers or projects are concerned. These readers criticize and comment on the papers, judge the accuracy, general quality, and scientific and/or pedagogic merit, and either accept, require revision, or reject them.

If this paper seems to need further revision, please make comments on a separate sheet of paper or, if it is acceptable, please so indicate. When you are ready, please return it and your comments to Ketchum 306E by campus mail. If you have indicated acceptance, we will mail to you a Certificate of Examination which when signed by all three readers will indicate to the Graduate School that the paper has been accepted in lieu of the comprehensive examination. This form must also be returned to us. The last day for acceptance for students receiving their degrees this May is 30 April according to the Graduate School calendar. If revisions are necessary, students usually appreciate being so informed as early in the semester as possible.

If you have questions of any sort, please do not hesitate to call any weekday afternoon, extension 6093. We are grateful that you are serving as a reader and extend our thanks accordingly.

Best wishes,



Claire Steffens
Administrative Assistant

MASTER OF BASIC SCIENCE Degree Program University of Colorado

the program

The program is an interdisciplinary one leading to the Master of Basic Science degree. It provides an opportunity for present and prospective high school and junior high school teachers, and others, to continue subject matter training in mathematics, museology, and the natural sciences at advanced undergraduate and graduate levels. The student may elect the mathematics, museology, or science option as described below. Wide latitude is possible in the details of a degree plan so that each student may follow a course of study most pertinent to his or her interests. The degree plan must be approved by the executive committee.

All courses credited toward the degree must be taken at the University of Colorado, on the Boulder, Colorado Springs, or Denver campuses, over a period of five years or six successive summers.

Requirements for Admission

1. General regulations for admission to the Graduate School apply.

2. A student must present at least 40 semester hours in the natural sciences and mathematics, preferably including one year of calculus. Students may be admitted to the program with a deficiency in calculus, but must remedy the deficiency within two years after the admission by completing one year of calculus (or other courses in mathematical subjects on approval by the executive committee) with a grade of C or better.

Requirements for Master of Basic Science Degree

1. General regulations of the Graduate School governing the award of the master's degree apply except as modified below.

2. *Graduate Record Examination.* Each student is required to take the GRE aptitude test within a semester after admission to the program as an aid in the planning of his degree program.

3. Thirty semester hours of courses numbered 300 and above in two or more of the departments listed below. Of these 30, 12 hours or more must be courses numbered 500 and above. Anthropology (museology option only); astro-geophysics; environmental, population, and organismic biology; chemistry; computer science; geology; mathematics; molecular, cellular, and developmental biology; museum (museology option only); and physics and astrophysics. See mathematics, museology, and science options below.

4. *Paper/Project.* Completion of a paper or project on a scientific or pedagogical topic approved by the executive committee. (This is in lieu of the comprehensive examination.)

5. *Minimum Grade-Point Average.* Courses on the 300 and 400 level will be accepted toward the degree only with grades of A or B; 500- and 600-level courses will be accepted toward the degree with

the options

grades of A, B, or C. The student must have a B average in all courses taken subsequent to admission to the program, including courses not actually offered for the degree.

Mathematics Option

1. A reasonable degree of competence is required in the fields of analysis, algebra, and geometry. A minimum of 15 semester hours of upper division courses (300-level or above) in mathematics must be offered for the degree, including at least 3 hours of analysis, 6 hours of algebra, and 3 hours of geometry.

2. One upper-division sequence of at least 6 semester hours in any of the sciences enumerated above. With permission, two independent one-semester courses in the same area may be substituted for the one-year sequence.

3. Upper-division electives in science, mathematics, or computer science, to complete an approved 30-hour degree plan. Of these 30, 12 hours or more must be from courses numbered 500 and above. The 30 hours may also include 3 semester hours of courses or seminars in secondary school mathematics teaching, history of mathematics or science, or philosophy of mathematics or science.

Museology Option

1. At least 8 but not more than 12 semester hours of courses offered by the museum. Alternatives are the sequence Musm. 401-402-403; or Musm. 401 and a selection of additional courses in museum. Three to 6 semester hours of courses in the College of Business and Administration are recommended. The total museum-business semester hours may not exceed 15.

2. An upper-division sequence (300-level or above) of at least 6 semester hours in one of the departments (other than museum) represented in the program.

3. Upper-division electives in science, mathematics, or computer science to complete an approved 30-semester-hour degree plan. Of these 30, 12 hours or more must be from courses numbered 500 and above.

Science Option

1. An upper-division sequence (300-level or above) of at least 6 semester hours in each of two of the sciences named above. With permission, two independent one-semester courses in the same area may be substituted for one of the one-year sequences.

2. Upper-division electives in science, mathematics, or computer science, to complete an approved 30-semester-hour degree plan. Of these 30, 12 hours or more must be from courses numbered 500 and above. The 30 hours may also include 3 semester hours of upper-division courses or seminars in secondary school teaching, history of science, or philosophy of science.

MASTER OF BASIC SCIENCE PROGRAM, KETCHUM 306E, UNIVERSITY OF COLORADO, BOULDER, COLORADO 80302, telephone (303) 492-6093, OR INQUIRE GRADUATE SCHOOL, UNIVERSITY OF COLORADO AT DENVER, 1100 14th STREET, DENVER, COLORADO 80202, telephone (303) 892-1117, extension 414.

UNIVERSITY OF COLORADO
Taximetrics Laboratory
Department E.P.O. Biology
Boulder, Colorado 80302
Phones: 492-6909
492-8598

Sept. 17, 1975

Master of Basic Science Program
Ketchum 306E
Campus

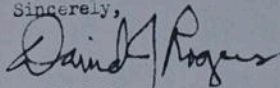
Attention: Ms. Steifens

Dear Ms. Steifens:

I enclose my recommendation for Mr. Pedro Garrido, who I understand is applying for admission to your program.

As I understand it, it must be stated that someone will be willing to oversee the production of a scholarly paper as one of the requirements for completion of this program. Since I have worked for some time with Mr. Garrido, I will be pleased to serve in this function. While there is, as yet, no title for the paper to be written, the nature of the paper is a comparative study of new computer-aided methods in biological systematics, and area of specialization and interest to me.

Sincerely,



David J. Rogers
Professor of Biology

SEP 12 1975

Department of Environmental,
Population and Organismic Biology

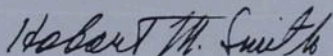
June 18, 1974

To whom it may concern:

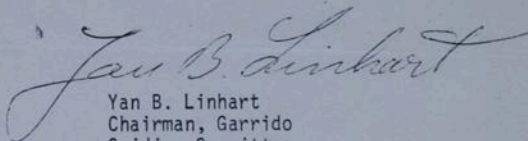
This is to certify that Mr. Pedro Garrido has satisfactorily completed one academic year of study in the Department of Environmental, Population and Organismic Biology at the University of Colorado.

During his stay, Mr. Garrido demonstrated great competence in Taximetric Methods, Computer Analysis, Angiosperm Evolution and other areas pertaining to his field of interest. He was working towards a Master's of Arts degree in Biology which normally takes two years of study. It was unreasonable to expect Mr. Garrido to finish such a program in nine months.

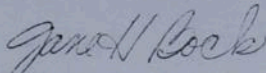
We the undersigned members of the Department of Biology were very pleased with Mr. Garrido's performance as a student, and feel that, had he been able to stay another year, he would have completed this program most successfully.



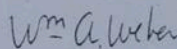
Hobart M. Smith
Chairman, Department EPO Biology



Yan B. Linhart
Chairman, Garrido
Guiding Committee



J. H. Bock
Member, Guiding Committee



W. A. Weber
Member, Guiding Committee

YBL:ds

STUDENT'S NAME GARRIDO PEDRO		STUDENT NO. 522-98-9044	SCHOOL GR	MAJOR 407	SEX 1	BIRTH DATE 12-07-39	BORN CLASS 1	STATE 6	HIGH SCHOOL 00
OFFICE OF ADMISSIONS AND RECORDS		UNIVERSITY OF COLORADO				BOULDER, COLORADO		GRADE REPORT	
GRADING SYSTEM		CAMPUS	COURSE TITLE		DEPT.	COURSE NO.	CREDIT HRS.	GRADE	POINTS
GRADE	CREDIT POINTS PER HOUR OF CREDIT	CAMPUS CODE							
A - SUPERIOR	4	1 - BLDG. EAM	1 ANGIOSPERM EVOLUTION		EP08	505	2	A	8.0
B - GOOD	3	2 - BLDG. MED	1 TAXIMETRICS		EP08	573	3	A	12.0
C - FAIR	2	3 - BLDG. CEN	1 INDEP STUDY-POP BIOL		EP08	599	5	A	20.0
D - MINIMUM PASSING	1	4 - BLDG. CEN	1 SEM-ENVIRON BIOLOGY		EP08	633	1	B	3.0
F - FAILURE	—	5 - COLO. SPR	1 SEM-POPULATION BIOL		EP08	693	1	A	4.0
H - HONORS	—	CENTER	1 INTRO TO COMPUTER SCI		C S	201	NC		
P - PASSES	—	6 - OTHER BLDG							
IP - IN PROGRESS	—	7 - OTHER BLDG							
IC - INCOMPLETE	—	8 - OTHER BLDG							
CN - CONDITION	—	9 - OVERSEAS STUDENTS							
NC - NO CREDIT	—								
IF NO GRADE LISTED, CHECK WITH INSTRUCTOR									
TERM CODE									
1 - FALL 2 - WINTER 3 - SPRING 4 - ALL WORK COMPLETED DURING SUMMER									
5 - ALL WORK COMPLETED END OF FIRST FIVE WEEKS SUMMER TERM									

GARRIDO PEDRO 163 VIA LAYETANA BARCELONA 9 SPA IN		TRANSFER NR.	ATTEMPTED SEMESTER HOURS						
			PENDING	H/P	FOR AVERAGE		POINTS	AVERAGE	
TERM	YEAR				FAILED	PASSED			
3	74					12.0	47.0	3.91	
CUMULATIVE						30.0	119.0	3.96	

DATE RECEIVED: 8/4/75

Routing:

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Abbott, Lois	_____	_____
April, Jay	_____	_____
Bailey, Mark	_____	_____
Bishop, Judy	_____	_____
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Hersh, Gil	_____	_____
Louis, Joan	_____	_____
McArthur, Greg	_____	_____
Mount, Janet	_____	_____
Rogers, Connie	_____	_____
Rogers, Dave	_____	_____
Saldana, Jose	_____	_____
Schiffman, R.	_____	_____
Slater, Chuck	_____	_____
von Borstell, G.	_____	_____
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Filing:

Original Garrido

Copies:

In	_____
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Internal	_____
Administration	_____
Fiscal/Contract	_____

Organization _____

Project _____

Proposal _____

COMMENTS:

Note probable
arrival of Garrido
Sept. 1.



AUG 04 1975

Institute of International Education

809 UNITED NATIONS PLAZA, NEW YORK, N.Y. 10017

July 30, 1975

Mr. Pedro Garrido
Via Layetana 163-2
Barcelona - 9
Spain

Dear Pedro Garrido:

Peter Fraenkel has asked that we provide you with an air ticket Barcelona/Boulder/Barcelona. Our travel agent is prepaying this air ticket for you in care of Iberia in Barcelona. If you have not heard from Iberia by the time you receive this letter, please call their Pre-paid Department.

From copies of the correspondence I have seen, I gather that you will travel to Boulder in September. However, there is no indication of your return date. Thus the enclosed DSP-66 shows the arbitrary dates September 1, 1975 through November 1, 1975. If you should stay longer than that, please let me know so that a supplementary DSP can be sent you.

With best wishes,

Sincerely,

Patricia Bain Mills
Program Administrator
Leaders & Specialists Division

Enc.

cc: Peter Fraenkel
David J. Rogers ✓

DATE RECEIVED:

Routing:

Initial

Abbott, Lois	_____	_____
April, Jay	_____	_____
Bailey, Mark	_____	_____
Bishop, Judy	_____	_____
Hanley, Jim	_____	_____
Hersh, Gil	_____	_____
Louis, Joan	_____	_____
McArthur, Greg	_____	_____
Mount, Janet	_____	_____
Rogers, Connie	_____	_____
Rogers, Dave	①	AMP
Saldana, Jose	_____	_____
Schiffman, R.	_____	_____
Slater, Chuck	_____	_____
von Borstell, G.	_____	_____
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Organization _____

Project _____

Proposal _____

COMMENTS:

JUL 29 1975

July 22, 1975

Mr. Peter Fraenkel
Adviser on International Programs
Ministerio de Educacion y Ciencia
Avda. del Generalisimo 82, 7^o iz.
Madrid -26

Dear Mr. Fraenkel:

Because Ms. Patricia Mills is out of the office I have today reviewed Pedro Garrido's file. I have requested our travel agency to wire ticket information to him in Barcelona which will enable him to make appropriate travel arrangements from Barcelona to Boulder, Colorado and return. The ticket will be pre-paid.

The only money remaining in the grant for Mr. Garrido is budgeted ~~for~~ international travel. I assume therefor that he will receive no maintenance allowance for the period of his stay in Boulder.

Please advise us if any other arrangements should be made for this grantee?

Sincerely,

Sue Liggett
Division Head
Leaders and Specialists

SL/ge

for your
information

DATE RECEIVED: MAY 16 1975

Routing:

	<u>Initial</u>
Abbott, Lois	_____
April, Jay	_____
Bailey, Mark	_____
Bishop, Judy	_____
Hanley, Jim	_____
Hersh, Gil	_____
Louis, Joan	_____
McArthur, Greg	_____
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Rogers, Connie	_____
Rogers, Dave	① _____
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Schiffman, R.	_____
Slater, Chuck	_____
von Borstell, G.	_____
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Copies:

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Administration _____
Fiscal/Contract _____

Organization _____

Project _____

Proposal _____

COMMENTS:

Dr. D. J. Rogers
Taximetrics Lab.
University of Colorado
Boulder

MAY 16 1975

Barcelona, May 10th, 1975

Dear Dr. Rogers:

Thank you for your letter of April 15th. As you request, my time availability is as follows: I can be in Boulder in July and back in Spain before October first of 75. (The deadline of my scholarship is in September 30th, and in the other hand I have to be teaching in October 2nd). The Ford Foundation pays me the trips and two weeks stay in Boulder, but I have savings to afford two months.

Let me know if what I have exposed fits in the plans you have figured out for me and in that case, please, tell me the definitive dates as Ford Foundation needs already to know them in order to arrange my schedule.

Sincerely yours

Pedro Ganado

Garrido

June 13, 1975

Mr. Pedro Garrido
Via Layetana 163-2
Barcelona - 9
Spain

Dear Pedro:

I am sorry that I have not had the chance to respond to your letter of May 10 sooner, but I have been on travel and have just returned. I think that your work can be accomplished in the time you have set and then we can work it out once you have arrived. Please send a copy of this letter to the Ford Foundation for their approval.

Sincerely yours,

David J. Rogers

DJR:hfr

Garrido/
Layetana

April 15, 1975

Mr. Pedro Garrido
Via Layetana 163-2
Barcelona - 9
Spain

Dear Pedro:

Thank you for your letter of April 2nd. I am pleased to hear that you can indeed be in Boulder this coming September. Please tell me how much time you can expect to spend with us. I want you to come and I would like to find the route for your receipt of a master's degree. If you tell me that you are interested in staying long enough to complete the time requirements, I feel certain that we can re-arrange past experiences so that you can successfully complete the work. It depends on your time availability. I look forward to your reply and be assured of my best wishes.

Sincerely yours,

David J. Rogers

DJR:hfr

DATE RECEIVED: 4/7

Routing:

	<u>Initial</u>
Abbott, Lois	_____
April, Jay	_____
Bailey, Mark	_____
Bishop, Judy	_____
Hanley, Jim	_____
Hersh, Gil	_____
Louis, Joan	_____
McArthur, Greg	_____
Mount, Janet	_____
Rogers, Connie	_____
Rogers, Dave	_____
Saldana, Jose	_____
Schiffman, R.	_____
Slater, Chuck	_____
von Borstell, G.	_____
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Original Pedro Garrido (people)

Copies:

In ✓ OK
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Administration _____
Fiscal/Contract _____

Organization _____

Project _____

Proposal _____

COMMENTS:

APR 07 1975

Barcelona, April 2nd, 1975

Dr. David J. Rogers
Taximetrics Lab.
University of Colorado
BOULDER

Dear Dr. Rogers:

Thank you very much for your letter of January 14th. It has taken me some time to rearrange my schedule, as you suggest in your letter. I can be in Boulder this September.

I wonder if I am being a problem for you. After all, the important thing is what I have learned in the Tax. Lab. and not to get a degree. Please tell me if you prefer that I change my mind in this point.

I still continue working on my project.

Sincerely

Pedro Garrido

January 14, 1975

Mr. Pedro Garrido
Via Layetana 163-2
Barcelona - 9
Spain

Dear Pedro:

I am sorry that I have not replied to your letter of December 15 sooner. Unfortunately, the time that you would like to come is very impractical for us because in these three months we have very many heavy obligations. May I suggest that you rather try to rearrange your schedule to be here this coming September.

There are further reasons for delay. First of all, I have to restructure your program to get a master's thesis permitted as the only continuing requirement. To tell you why this is true, the enclosed letter will explain to some extent. In other words, there is a considerable amount of politics that I have to go through before getting approval for you to receive a master's thesis. I am sorry that this is true, but it is the case and it will take me some time to change the minds of Professors Bock, Linhart and Weber. I trust that you can make arrangements to fit our program better.

Sincerely,

David J. Rogers
Professor of Biology

DJR:hf
Enc.

David for your info.

NOV 22 1974

copy of this in Pedro's
file.

June 18, 1974

To whom it may concern:

This is to certify that Mr. Pedro Garrido has satisfactorily completed one academic year of study in the Department of Environmental, Population and Organismic Biology at the University of Colorado.

During his stay, Mr. Garrido demonstrated great competence in Taximetric Methods, Computer Analysis, Angiosperm Evolution and other areas pertaining to his field of interest. He was working towards a Master's of Arts degree in Biology which normally takes two years of study. It was unreasonable to expect Mr. Garrido to finish such a program in nine months.

We the undersigned members of the Department of Biology were very pleased with Mr. Garrido's performance as a student, and feel that, had he been able to stay another year, he would have completed this program most successfully.

Hobart M. Smith
Chairman, Department EPO Biology

Yan B. Linhart
Chairman, Garrido
Guiding Committee

J. H. Bock
Member, Guiding Committee

W. A. Weber
Member, Guiding Committee

YBL:ds

DATE RECEIVED: DEC 23 1974

Routing:

	<u>Initial</u>
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April, Jay	_____
Bailey, Mark	_____
Bishop, Judy	_____
Hanley, Jim	_____
Hersh, Gil	_____
Louis, Joan	_____
McArthur, Greg	_____
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Rogers, Dave	_____
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Schiffman, R.	_____
Slater, Chuck	_____
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Administration _____
Fiscal/Contract _____

Organization _____

Project _____

Proposal _____

COMMENTS:



OCT 21 1974

Institute of International Education
809 UNITED NATIONS PLAZA, NEW YORK, N.Y. 10017

October 16, 1974

Dr. David J. Rogers
Professor of Biology
Department of Environmental
Population and Organismic Biology
University of Colorado
Boulder, Colorado 80302

Dear Dr. Rogers:

Thank you so much for your letter of October 9th which supplemented considerably my understanding of Pedro Garrido's program and problems.

I shall write to the Foundation today to see if they could consider supporting Mr. Garrido for another year. I rather doubt that they will do so, as the entire program will be terminated at the end of this academic year. Both the Foundation and I had been led to understand that the only financing which would be required would be that needed for a two-week to one-month stay in Boulder, and it was on this basis that the trip was considered.

I appreciate your interest in this matter and will forward your comments to Ford.

With good wishes,

Sincerely,

Patricia Bain Mills
Patricia Bain Mills
Program Administrator
Special Projects & Arts

Dr. D. J. Rogers
Taxometrics Lab.
U. of Colorado
Boulder

Barcelona, December 15th 1974

Dear Dr. Rogers :

I was very happy when I got your letter of August 21th.. My English is too poor to express my feelings when I read your answer. It encouraged me and I have been working on my project along these last months. I got new data and managed to get charanal and some others programs running and now finally I am writting the conclusions in a paper that could be called " The taxonomic value of the fruit of Hippocrepis L. : A numerical approach". I think it has enough interest to be presented as my thesis for the Master.

There is no problem for me to get fifteen days of permission to go to Boulder. It would give me sometime to discuss with you my thesis (in order to add or drop parts etc...) before my presentation.

About the time to go to Boulder I think the sooner I go the easier will be to get the financial support I had been promised.

The best date for me to go would be sometime in January, February or March, because later when the academic year finishes I have to examine my students and would be much more difficult to get permission for a trip.

Would you please tell me if you agree with all this and the dates are suitable for you. Also, perhaps, you could indicate me if I have to register now or when I will be in Boulder.

Thank you very much for your attention. Yours sincerely

Pedro Garrido

October 9, 1974

Ms. Patricia Bain Mills
Program Administrator
Special Projects & Art
Institute of International Education
809 United Nations Plaza
New York, New York 10017

Dear Ms. Mills:

I am responding to your letter of Sept. 23, with respect to Mr. Pedro Garrido, and his desire to return to the University of Colorado to complete his masters work under my direction.

I have written to Mr. Garrido and told him that I would be glad to have him back. However, he will have more to do than "defend his thesis", because, upon review, he needs to do more than just the defense of the thesis. I will write to him and tell him what is required, to see if he wants to continue to the point of completion of the master's degree. (One academic year should complete the work).

It is necessary for your understanding to know something of the history of Mr. Garrido's matriculation here, and some of the events which caused him not to be successful during the first year's tenure of his grant from you.

Mr. Garrido came to the University unannounced, without prior application to our department, or to me. He came during the summer of 1973, and spent the summer months under the direction of Dr. Charles Norris, during which time I was away, although I think that Garrido wanted to study under my direction. When I returned in the fall of 1973, Dr. Norris turned him over to me, and I acted as his unofficial professor. I put him to work learning that which he came here to learn, but without a clear picture (at the beginning) of his desire to complete a master's degree. I finally found out that he did want a degree, but then too late to establish the normal set of requirements, graduate committee, etc. By the time this was finally done, I had agreed to spend a leave of absence at FAO in Rome, starting in January of this year. So, I turned Mr. Garrido over to Dr. Yan Linhart of our department, even though Dr. Linhart could not give him continued instruction in the computer-aided methods that Mr. Garrido wanted. By mutual agreement of Dr. Linhart and two other members of the faculty, Garrido's program was changed from a masters program I to masters program II -- from thesis to no thesis. They did this considering what they thought to be Garrido's best interest. It turns out that Garrido's command of English was not what the committee thought to be adequate, and would have recommended that he participate in the English for foreign student program.

Ms. Patricia Bain Mills
October 9, 1974
Page 2

All of the forgoing is unfortunate for Mr. Garrido, but it might have been prevented had we had the normal admissions activities for his matriculation here. Mr. Garrido is a very intelligent, and fully capable individual, and for that reason, I think he can make it through with one more year, and at the same time, satisfying his primary requirement, to get a background in the rather new discipline I teach. I trust that you can now evaluate the whole, and provide Garrido with the necessary funds for continuation.

Sincerely yours,

David J. Rogers
Professor of Biology

DJR:js

DATE RECEIVED: 9/29

Original:

<u>Route</u>		<u>Initial</u>
JEA	_____	_____
LA	_____	_____
CHN	_____	_____
JRH	_____	_____
DRJ	_____/____	_____
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Admin _____
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Function _____

Organiz _____

Proj _____

Prop _____

COMMENT:

*Institute of International Education*

809 UNITED NATIONS PLAZA, NEW YORK, N.Y. 10017

September 23, 1974

Dr. David J. Rogers
Professor of Biology
Taximetries Lab.
Dept. EPO Biology
University of Colorado
Boulder, Colorado 80302

Dear Dr. Rogers:

As you know from Pedro Garrido's letter of August 7th, he hopes to return to Boulder some time before September 1975 to defend his thesis.

At the request of the Ford Foundation, I am writing to ask if you can give us any assurance that Garrido's plan will be successful. I am aware that you cannot guarantee the results, but the Foundation wishes to know if there is a good likelihood of success before supporting the project.

With good wishes,

Sincerely,

Patricia Bain Mills
Program Administrator
Special Projects & Arts

Pedro Garrido
Via Layetana 163. 2º
Barcelona - 9
Spain

Taximetrics Lab.
Dept. EPO Biology
Univ. of Colorado
Boulder, Colo. 80302
August 21, 1974

Dear Pedro:

I was very glad to get your letter of August 7th, because I wanted in some way to help out with your problem, which Gil Hersh had told me about, and I was very sorry to learn what had happened to you.

Now that you have written, I will be glad to continue to work with you on the plan that you describe in your letter. I expect to be here at the University on a regular basis for some time, and should be available when you want to return to complete your degree.

I am sorry that the committee you had after I left was unable to understand what you were doing, nor your needs.

When you have more definite plans, please let me know.

Sincerely Yours,

David J. Rogers
Prof. of Biology

Best regards to you from Gil and Jay and Lois.

Dr. David J. Rogers
Taxometrics Lab.
U. of Colorado
Boulder

Parque de los, August 7th 1974

Dear Dr. Rogers:

I have two principal reasons to write you this letter. First, to expose you my point of view of what happened to me along the spring semester when you were in Rome. Second, because I feel you are the only person in C.U. that can help me.

Since you leave a series of facts made things more and more difficult to me. First of all my committee did not accept my work based on the fruits and characters of Hippocrepis as a theme for a master's thesis. As a consequence I had to take more courses to complete 30 credits instead of 24 as before. In such a condition I had no time leaved to reviewing extensively for my comprehensives. Also, during my stay in C.U. I tried to learn new things rather than reviewing subjects I already had studied several years ago.

In resume: I think that my committee never fully understood my problems and aims while I was in C.U. I was judged based only on the comprehensives without having considerations of my grades (3.96 average) and my project on Hippocrepis.

I have explained all to my sponsors (Ford Foundation + INCIE). They are glad with my grades and my job and they agree to give me an allowance for 1 or 2 weeks trip to Boulder if it is enough to complete my Master. This trip should be done before September 1975 which is the deadline of this Ford Foundation program in Spain.

As I already have all the prerequisites (30 credits, including 2 seminars) the only thing leaved for me to get a M.H. is the defense of my thesis and I believe it will not take more

For my part, I am still working on my plants (Now in the "Numerical Taxonomy" course in Lisbon (course)). I am pretty sure I'll have enough results to write a master thesis soon.

Now, may I ask you a question? : if what I propose is technically possible, would you support my plan and be my adviser in the thesis?

My plan is as follows:

- 1) I have the prerequisites (done in Boulder 73-74)
- 2) Continue to work and complete my M.A. thesis in Barcelona (74-75)
- 3) Go to Boulder and talk with you and defend my thesis (Sometime before Sept. 75)

I would appreciate very much if you had a few minutes to think about it.

With my best wishes

Pedro Gamito

Via Layetana 163.- 2°
BARCELONA - 9
SPAIN



UNIVERSITY OF COLORADO
OFFICE OF ADMISSIONS
AND RECORDS

Regent Hall 125
Boulder, Colorado 80302
(303) 443-6130

August 14, 1973

TO: Graduate Department of Biology
FROM: James C. Homan, Administrative Interne
RE: Mr. Pedro Garrido

The above named student is seeking admission to the MA program in biology. He has been attending CU as a special student during the summer term of 1973 and I understand that you have had a chance to talk with Pedro and that you have indicated to him you are ready to admit him into the master's degree program. The enclosed material is all that we have received on him to date. We did not receive a copy of his GRE scores.

The applicant's previous academic experience includes graduation from a University in Spain which should more than qualify him for admission to a graduate program in the United States. A GPA equivalent is not able to be computed from their system of grading.

Enclosed are copies of three letters of recommendation which we have received and they support his application for graduate school.

The applicant is extremely interested in becoming as proficient in teaching of biology as is possible. Perhaps courses from the School of Education could be incorporated into his master's degree program with your department.

JCH:ld

Enclosures



Ministerio de Educación y Ciencia
Centro Nacional de Investigaciones
para el Desarrollo de la Educación

CONFIDENCIAL REPORT ON APPLICANT

Name : Pedro María GARRIDO Leguilla
Program : Ford Foundation
Category : Graduate Student

1. Personality
2. Emotional Stability
3. Seriousness of Purpose
4. Academic Record

5. Potencial for Future Contribution to the Spanish Educational Reform
6. Preferences for U.S. Universities
7. Knowledge of English
8. Financial Information

1. Very agreeable
2. Stable
3. Good

4. Undergraduate Major : Biology (five years)
Licensed in Biology at the University of Barcelona (1964)
PhD courses

5. High School Teacher (Sciences), Barcelona
Also teaching and doing research at the University of Barcelona

6. First choice : University of Colorado, Boulder

7. ALIGU written score 72 plus oral rating 90 (Date : April 24, 1972)
Intends to take TOEFL in October 1972
Needs four weeks of English training

8. He will receive no salary during his stay in the United States
No dependents

Name and Title : Emilia Ruiz Campuzano Jefe de la Oficina de Programas Internacionales
Emilia Ruiz Campuzano Date : June 5, 1972

Feдро M. Carrido

COUNTRY: Spain

CURRICULUM VITAE

INSTRUCTIONS

The curriculum vitae should be in the form of an essay and not a listing of facts. It should include information concerning your past education, practical experience, special interests, specific purpose in applying for a scholarship in the United States (do not mention specific institutions in connection with statement of purpose), and plans for

work after returning to home country. Advanced students should comment on the number of years of duty or practical work already completed in the field in which academic work will be done in the United States, and describe briefly the most advanced courses already pursued in their field of study.

Following your instructions, I will explain, in the first place, the points relative to my studies, practical experience, and the fields in which I am mainly interested. Only at the end, and in order to make comprehension easier, I will give a short list of positions occupied and their dates to reinforce my statements of the first part.

During seven years I attended the Jesuits' Secondary School "San Ignacio" in Barcelona, where I obtained the necessary Certificate (Bachillerato). Afterwards I studied at the university of Barcelona, from 1959/60 to 1965/64, in which year I took my degree (Licenciado en Ciencias Biológicas). In 1965/66, after finishing my military service as a reserve officer, I attended the monographic courses previous to the degree of doctor.

I began my professional work as a teacher (by contract) at the state-supported High School (Instituto Nacional de Enseñanza Media) in Jaca (Huesca), where I gave classes on Biology. Very soon I realized that I liked teaching and, therefore, I prepared the competitive examination for the degree of "Profesor Agregado" in Biology, succeeding at the first attempt. (Madrid, December 1966). Once an official professor, I kept on teaching till the end of 1967. At that moment, I received an offer for teaching as a full time professor at the Faculty of Educational Sciences of the University of Quindío (Colombia). As it seemed interesting, I accepted this offer, and during all 1969 I taught the freshman and the fifth course at that university. This has been a very exciting experience for me. Most of my pupils had in mind to devote themselves to teaching Biology, which helped me to get familiar with the University teaching techniques of that country.

Back home I continued teaching at the state-supported High School in Sabadell (Barcelona) and, at the same time, at the Autonomous University in Barcelona, where I conducted the practical classes in the laboratories of the freshman. This new experience only increased my interest for teaching biology.

The following year, I was commissioned by the Spanish Ministry of Education and Science (Ministerio de Educación y Ciencia), of which -as said above- I am a professor, to go to the Republic of Guinea Equatorial, in order to help developing the studies and teaching of Biology that had been neglected since the independence of that country.

After a year I went back to Barcelona, where I am now a professor at the state-supported High School "Diputación Baronesa" in Lapeña.

My experience has shown me that usually the low level and lack of scientific profit of pupils is partially due to the great confusion and variety of syllabus as well as to the not very pedagogical methods that are usually used. During the time I stayed in America, I got to know and appreciate the style and syllabus of the Biological Science Curriculum Study. Since then I have been interested in specializing in methodology and didactics of biology.

With regard to my future, I hope that, when I am back in Spain, I will increase knowledge and further experience I want to gain in order to let me improve the professional level of my colleagues. I am also interested in collaborating with the organizations that are working for the training of teachers of biology. Then, too, I will continue working in the field of biology.

DATE

SIGNATURE OF APPLICANT

May 22nd - 1972

PRIVATE AND CONFIDENTIAL

Send directly to the Selection Committee in the applicant's country or to the Cultural Affairs Officer of the diplomatic mission in the applicant's country. Under no circumstances should the completed form be returned to the applicant.

This letter should be typewritten and in English, if possible. If not in English, an accurate translation must be attached.

AN APPLICATION FOR GRADUATE ADMISSION TO A UNIVERSITY IN THE UNITED STATES OF AMERICA
AND FOR A FELLOWSHIP, SCHOLARSHIP, ASSISTANTSHIP OR OTHER
EDUCATIONAL EXCHANGE GRANT

LETTER OF REFERENCE

This letter of reference must be written by a teacher under whom the applicant has studied or pursued research in his field of study or by someone who has supervised him in work related to his proposed field of study.

NAME OF APPLICANT: Pedro Ma Garrido

COUNTRY: Spain

HOW LONG HAVE YOU KNOWN THE APPLICANT? Since 1960.

IN WHAT CAPACITY HAVE YOU KNOWN THE APPLICANT? Pupil.

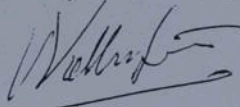
YOUR STATEMENT CONCERNING THE APPLICANT:

We would appreciate your candid opinion of the applicant's scholastic ability and motivation for graduate study in the United States. Please include your estimate of his personal and intellectual qualifications as they affect his academic capability, personality, character, adaptability, emotional stability and seriousness of purpose. Your comments will be kept in the strictest confidence. Thank you for your cooperation.

The applicant, Mr. P. Garrido, has been my pupil in the academic years 1960-61 and 1961-62. During that time he regularly attended my classes on animal and vegetal Histology showing great interest and, therefore, profiting highly from them. He attends the theoretic classes as well as the practical ones working in the laboratories and with the microscope in which work he was specially interested. From observing him making cuts, tictures and microscopie preparation deduce that he had a flexible and researching mind.

He has a natural gift for teaching and has been devoted to it since he took his degree. Actually he is interested in methodology and didactics of Biology. He knows several works published on these subjects in the U.S.A. As he considers them of a high level and very useful he wishes to widen his knowledge of these techniques in the States which, to my opinion is the most convenient thing to do.

As far as I know him Mr. Garrido proves to have a good, quiet temper and rectitude of mind.



How would you rank the applicant in relation to other students in his class? (For example, would he be third highest out of fifteen students or fifth out of eight students.) He was one of the first three pupils I had in my class of those days.

How would you judge his potential capacity and promise for undertaking a rigorous program of graduate study in the United States?

I esteem him as entirely qualified to prepare for a doctorate or a similar degree

Name and Title (print): Francisco Vallmitjana Novira, Catedrático de Histología.

Signature: _____ Date: May-26nd-1972

Address: Laboratorio de Histología, Facultad de Ciencias, Universidad de Barcelona, Barcelona, Spain.

PRIVATE AND CONFIDENTIAL

Please return directly to the Selection Committee in the applicant's country or to the Cultural Affairs Officer of the U.S. diplomatic mission in the applicant's country. Under no circumstances should the completed form be returned to the applicant.

This letter should be typewritten and in English, if possible. If not in English, an accurate translation must be attached.

AN APPLICATION FOR GRADUATE ADMISSION TO A UNIVERSITY IN THE UNITED STATES OF AMERICA
AND FOR A FELLOWSHIP, SCHOLARSHIP, ASSISTANTSHIP OR OTHER
EDUCATIONAL EXCHANGE GRANT

LETTER OF REFERENCE

This letter of reference must be written by a teacher under whom the applicant has studied or pursued research in his field of study or by someone who has supervised him in work related to his proposed field of study.

NAME OF APPLICANT Pedro GARRIDO LAGUNILLA COUNTRY Spain

HOW LONG HAVE YOU KNOWN THE APPLICANT? 10 years ago

IN WHAT CAPACITY HAVE YOU KNOWN THE APPLICANT? University student (Biological Sciences)

YOUR STATEMENT CONCERNING THE APPLICANT:

We would appreciate your candid opinion of the applicant's scholastic ability and motivation for graduate study in the United States. Please include your estimate of his personal and intellectual qualifications as they affect his academic capability, personality, character, adaptability, emotional stability and seriousness of purpose. Your comments will be kept in the strictest confidence. Thank you for your cooperation.

sufficient academic capability
stable, pacific and serious character

How would you rank the applicant in relation to other students in his class? (For example, would he be third highest out of fifteen students or fifth out of eight students.) superior intermediate

How would you judge his potential capacity and promise for undertaking a rigorous program of graduate study in the United States?
positive

Name and Title (print) Dr. Oriol de Bolbs, Botany Professor (Chairman), Science Fac.
University of Barcelona

Signature [Signature] Date 23 May 1972
Address Dept. of Botany, Sc. Fac., Univ. of Barcelona (Catalonia, Spain)

PRIVATE AND CONFIDENTIAL

Please return directly to the Selection Committee in the applicant's country or to the Cultural Affairs Officer of the U.S. diplomatic mission in the applicant's country. Under no circumstances should the completed form be returned to the applicant.

This letter should be typewritten and in English, if possible. If not in English, an accurate translation must be attached.

AN APPLICATION FOR GRADUATE ADMISSION TO A UNIVERSITY IN THE UNITED STATES OF AMERICA
AND FOR A FELLOWSHIP, SCHOLARSHIP, ASSISTANTSHIP OR OTHER
EDUCATIONAL EXCHANGE GRANT

LETTER OF REFERENCE

This letter of reference must be written by a teacher under whom the applicant has studied or pursued research in his field of study or by someone who has supervised him in work related to his proposed field of study.

NAME OF APPLICANT Pedro María Garrido Lagunilla COUNTRY Spain
Pedro María Garrido Lagunilla

HOW LONG HAVE YOU KNOWN THE APPLICANT? since several years

IN WHAT CAPACITY HAVE YOU KNOWN THE APPLICANT? as a student in my course of general Ecology,
and from time to time afterwards

YOUR STATEMENT CONCERNING THE APPLICANT:

We would appreciate your candid opinion of the applicant's scholastic ability and motivation for graduate study in the United States. Please include your estimate of his personal and intellectual qualifications as they affect his academic capability, personality, character, adaptability, emotional stability and seriousness of purpose. Your comments will be kept in the strictest confidence. Thank you for your cooperation.

He was a good student, of moderate intellectual capacity, but dedicated and hard working. After his graduation we have had occasional contacts, in meetings, etc., and I got the impression that he was working seriously and was really interested in being a good teacher. As far as a professor can have an opinion of a student in a rather numerous class, I have the impression that he goes well along with people, and cooperates with team work.
efficiently in

How would you rank the applicant in relation to other students in his class? (For example, would he be third highest out of fifteen students or fifth out of eight students.) In the top fourth of a class of about 20

How would you judge his potential capacity and promise for undertaking a rigorous program of graduate study in the United States?

Fair.

Name and Title (print) Ramón Margalef, Professor of Ecology, University of Barcelona

Signature R. Margalef Date May 22, 1972

Address Department of Ecology, Faculty of Science, University of Barcelona

**UNIVERSITY OF COLORADO
OFFICE OF ADMISSIONS AND RECORDS
APPLICATION FOR SPECIAL STUDENT ADMISSION**

DO NOT COMPLETE

Typewrite or print in ink. All information below must be coded and/or completed. Enter the appropriate code in the box provided. Applications will be accepted only while vacancies exist for special students. *W/L sent 5-3-73*

GARRIDO PEDRO
Last Name First Name Middle Name Maiden Name

SEX CODE:
1—Male
2—Female

Social Security number

Student number (if a former U. of C. student)

MARITAL CODE:
1—Single
2—Married

Give name under which you were last registered at the U. of C. if different from above: _____

163 Via Layetana BARCELONA-9 SPAIN
Home Address: Number and Street City State Zip Code Area Code and Phone Number
Parent or Spouse Name and Address LAGUNILLA MERCEDES MOTHER
Last Name First Middle Initial Relationship
163 VIA LAYETANA BARCELONA-9 SPAIN
Number and Street City State Zip Code Area Code and Phone Number

CITIZENSHIP CODE:
1—U.S. Citizen
2—Not a U.S. Citizen

TYPE CODE:
2—Have not attended U. of C. previously
3—Have attended U. of C. previously

My age is: 33

BIRTH PLACE: BARCELONA (SPAIN)

I have a high school diploma or a G.E.D. Certificate of Equivalency: Yes ☒ No ☐
I am eligible to return to all collegiate institutions previously attended: Yes ☒ No ☐
Is your permanent home at present the same as your father's? Yes ☒ No ☐ If not, give name of person with whom you reside _____ Relationship _____

If your home is in Colorado, when did this residency begin for you? _____
For father? _____ For spouse? _____ Have you filed a Colorado state income tax return? Yes ☐ No ☐ For what years? _____ If you are less than 21 years of age, has your father or legal guardian filed a Colorado state income tax return? Yes ☐ No ☐ For what years and name of person filing _____
Has your husband/wife filed a Colorado state income tax return? Yes ☐ No ☐ For what years? _____
If married, is your spouse a student? Yes ☐ No ☐ List all employment you and your spouse (if married) have held in the past 12 months: _____

Applicant/Spouse Name Employer Hours per Week Phone Number City and State Inclusive Dates
APPLICANT SPANISH MINISTRY 40 BARCELONA 1966/-
OF EDUCATION SPAIN

BIRTHDATE:
1939 12 7
YEAR MONTH DAY

TERM APPLYING FOR:
1—Fall
3—Spring
4—Summer

Military service dates: From 1964 to 1965 Have you ever been under treatment for a serious emotional or major physical illness? Yes ☐ No ☒ Have you ever been convicted of a felony or misdemeanor? Yes ☐ No ☒ Have you ever been convicted of any crime or been disciplined by any institution of higher education for actions involving campus disruptions? Yes ☐ No ☒ If you answered "yes" to any of the above three questions, please attach a letter of explanation.

CAMPUS CODE:
1—Boulder
3—Medical Center
4—Denver Center
5—Colorado Springs Center
9—All others

I hereby certify that to the best of my knowledge the information furnished on this application is true and complete without evasion or misrepresentation. I understand that if found to be otherwise it is sufficient cause for rejection or dismissal. I also understand that if I have not been classified a resident by the University of Colorado and have not petitioned for such a change before registration that my University classified status will not change until the next semester after the proper petition is approved. Proof of age and proof of local employment or additional information may be required by an admissions officer.

MAJOR CODE:
833—I do not have a college degree
833—I have a bachelor's degree
837—I have been admitted to the Teacher Education Program

Date: Jan - 28 - 1973 Applicant's Signature: Pedro Garrido

Form 22A (Rev. 2/72)

I B

Institute of International Education
UNITED NATIONS PLAZA, NEW YORK, N.Y. 10017

December 15, 1972

Mr. Jim Roman
Assistant Director
Graduate and International
Student Admissions
Office of Admissions and Records
University of Colorado
Regent Hall 125
Boulder, Colorado 80302

Dear Jim Roman:

Both Pedro Garrido and the Ford Foundation approve completely of the plan that Mr. Garrido arrive in Boulder on June 7 to spend the summer working with the Biological Science Curriculum Study and taking one education course.

On June 18 he will take the GRE test in Boulder so that by August you will know whether he can be admitted as a degree candidate in the Department of Education. If he is admitted as a candidate, his fellowship will be extended until the end of May (1974) or even through the summer session if that proves necessary.

If he does not successfully complete the GRE, he will remain in Boulder for the 1973 fall semester as a non-degree student and return to Spain in December.

Again, with many thanks to you and Bob Hefling for all of your help.

Sincerely,


Patricia Bain Mills
Program Administrator
Special Projects & Arts

11

*For your information
Pat Weiss*

Institute of International Education
800 UNITED NATIONS PLAZA, NEW YORK, N.Y. 10017

December 16, 1972

Mr. Pedro M. Garrido Lagonilla
Via Legation, 102
Barcelona 9, Spain

Dear Mr. Garrido:

I am happy to be able to confirm to you that you have been selected to receive a fellowship under the Ford Foundation's program of collaboration with the Educational Reform in Spain. The grant is designed to give you an opportunity to do research in the methodology and didactics of biology.

As you know, you are expected to arrive in Boulder, Colorado, by June 7th, 1973, so that you may begin your work for the summer semester. We understand that you are to take the GRE test in Boulder on June 18th. If you pass this examination, you will be admitted as a graduate student in the School of Education for the academic year beginning in September. Should you fail the test, you will be admitted as a non-degree candidate for the fall semester only.

The terms of your award are as follows. Before you leave Spain, you will receive our check in the amount of \$70 representing your preparatory allowance (\$50) and in-transit allowance (\$20), and an economy class air ticket for the routing Barcelona-Denver with a coupon for up to 10 kilos excess baggage. At the end of your stay in Boulder you will receive a return air ticket, excess baggage coupon, and there will be an allowance of up to \$100 for the sea shipment of your effects.

Your tuition and fees at the University of Colorado will be paid for you, and you will receive a monthly stipend of \$215 to cover the cost of your housing, meals, local transportation and miscellaneous expenses. In addition, there is an allowance of \$200 for the purchase of books and up to \$250 for program-related travel recommended by your advisor.

At no expense to you, IIE will provide you with insurance of up to \$25,000, in the case of accidental death or dismemberment, as well as a policy for basic medical insurance of up to \$1000 (with a \$10 deductible clause). In this connection, may I ask that you complete, sign and return to me the enclosed beneficiary card.

TELEPHONE: TN 7-0400; CABLE ADDRESS: "INTERED" DOMESTIC OFFICES: CHICAGO, DENVER, HOUSTON, SAN FRANCISCO, WASHINGTON, D. C.
OVERSEAS OFFICES: NAIROBI, KENYA; LIMA, PERU; BANGKOK, THAILAND; PARIS, FRANCE

Dr. Pedro M. Garrido Leguilla

-2-

December 18, 1972

If the terms of this award as outlined above are acceptable to you, please sign and return to us the duplicate copy of this letter.

All future correspondence regarding your fellowship should be addressed to

Patricia Sain Mills
Program Administrator
Special Projects & Arts

who will be administering your award.

I should like to take this opportunity to wish you a rewarding year at Boulder.

Sincerely yours,

Richard B. Myer
Vice President
Special Projects & Arts

Enclosures

cc: Dr. Peter Frankel
Ms. Emilia Pado Comisario
Mr. Robert J. Hafling, Graduate and Inter'n'l Student Admissions
Ms. Phyllis Cotton, III Denver

Your signature: _____ Date: _____

UNIVERSITY OF COLORADO

BOULDER, COLORADO 80302

In mailing, please address—Regent Hall 125

OFFICE OF ADMISSIONS AND RECORDS

November 7, 1972

Mrs. Patricia Bain Mills
Program Administrator
Institute of International Education
809 United Nations Plaza
New York, New York 10017

Dear Mrs. Mills:

This letter is a follow-up of our telephone conversation on October 25. I apologize for the confusion caused by my letter of October 6.

Mr. Garrido could enter the University of Colorado in June or August of 1973 as a special student. I believe that he would derive the greatest benefit from his scholarship if he could come in June and stay through the fall semester.

The Biological Science Curriculum Study which he is interested in is not a department of the University. If Mr. Garrido came here he could confer with people in the Study, but he would be taking courses in another discipline. He would not receive a degree or obtain a certificate at the end of his stay in Boulder. Currently, Mrs. Liggett of your office has another student from Afghanistan who has similar interests but now wishes to obtain graduate status and earn a degree. If Mr. Garrido has any plans for a degree, he would have to take the Graduate Record Examination and submit a formal application to the department concerned. The GRE scores are not required if he is coming only as a special student for a short period of time.

This student has indicated on his application that he is single. If he comes for the summer term he will be able to live in the University residence halls. If he does not come until August he will have a more difficult time obtaining residence hall accommodations. However, the Foreign Student Adviser on this campus may be able to assist him in that regard, providing the FSA has been given several months lead time to obtain housing.

RECEIVED

NOV 8 1972

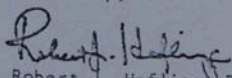
FOREIGN STUDENT CENTER
UNIVERSITY OF COLORADO

Gene -
For your information.
Pete Garrido has been awarded
a Ford Foundation Grant for
no more than two terms.
Please note on p. 2 that I have
used your name freely.
Bob -

Mrs. Patricia Bain Mills
November 7, 1972
page 2

Please do not hesitate to contact me if you have further questions regarding this student's attendance at the University of Colorado. I will be out of the office for approximately five weeks beginning November 17. If additional problems arise while I am gone, I would suggest that you contact Mr. Eugene Smith, the Foreign Student Adviser.

Sincerely,



Robert J. Hefling, Director
Graduate and International
Student Admissions

RJH:j

DJR/BJ

Letters of recommendation dated 1/28/80:

Dr. William Laughner
Biology Department
Hiram College
Hiram, OH 44234

Dr. Patricia Johnson, Chairman
Department of Biology
Box 377
Vassar College
Poughkeepsie, NY 12601

Search Committee
Department of Biology
Kenyon College
Gambier, OH 43022

14 April 80
✓ Dr. Margaret S. Hertz
Chairman
Dept. of Biology
C.W. Post Center
Greenvale, N.Y. 11548

adjust #1

Faculty position you mentioned
in your letter.

22 January 1980

Please write letters of recommendation to:

Colleagues

✓ Search Committee, Department of Biology
Kenyon College
Gambier, Ohio 43022

"tenure-track faculty:

~~Botanist~~
rank open"

✓ Dr. Patricia Johnson, Chairman ~~(redacted)~~
Department of Biology, Box 377
Vassar College
Poughkeepsie, New York 12601

Asst. Prof., Botany

✓ William Laughner
Biology Department, Hiram College
Hiram, Ohio 44234

"tenure-track position,

~~rank open~~
Botanist"

In addition, you may be asked to write letters, or receive telephone calls from:

H. P. Little, San Francisco, California (I don't know the name of his organization)

Department of Biology, University of Alabama, Huntsville

Department of Biology, University of California, Los Angeles

Department of Biology, Texas A & M University, College Station

Dr. J. N. Owens, Department of Biology, University of Victoria, British Columbia

Q

Q

Dear Q:

I write to support the candidacy of Mr. Barry C. Johnston for the position announced recently for a Q. Barry expects to receive his Ph.D. under my direction at the end of this semester.

Barry is one of the best prepared candidates I have had the privilege to guide in a doctoral program. He is exceptionally well-trained in a wide variety of subjects, from physics and engineering, mathematics and computer science, through all requirements in a department of biology including population biology, ecology and taxonomy, as well as a number of other subjects (physiology, genetics, et al.). He has wide experience in teaching, from high school through undergraduate math and biology teaching programs abroad and in this country. He has had experience as a teaching assistant in this department (general biology and plant taxonomy) as well as botanical research assistant at the Museum here. He has worked in private industry, for the USDA (Forest Service) in both field and laboratory. He is very well qualified in languages, speaking the Hausa language of Nigeria with fluency, reads and writes Russian and Latin, reads German fluently, and reads acceptably several of the romance languages. He is a dedicated naturalist, and is recognized as one of the major experts on rare and endangered species of the Rocky Mountains, particularly Colorado. He has been a joint author with several professionals on a variety of subjects, and is single author on a paper accepted by the refereed journal Taxon.

Barry's research for the Ph.D. has centered on population problems in several species complexes of the enormous rosaceous genus Potentilla, which has presented sets of problems many students have attempted, but few have solved. Barry proved his research capabilities by recognizing that the problems in the genus were at the level of populations, and that settling problems of variability at that level would provide the key to problems of taxonomy at the formal hierarchical levels above the population. His research design is outstanding, his processes of analyses are innovative and appropriate to the task, and he is bringing

8

8

Page 2

to bear many of the former disciplines in which he was outstanding as a student, including mathematics and statistics, as well as a number of biological disciplines. He is a prodigious worker, and produces results that would be beyond the capability of many other students.

Barry is helpful to his peers, and his maturity gives him a perspective lacking in the normal-aged graduate student. He is sought out by both students and faculty for advice and instruction. He has taught several sections of my course in the Principles of Taxonomy and Computer Use, and has performed very well. He has a pleasant speaking presentation and is well-organized in his lectures.

take out (With all of the above, it is delightful to discover that Barry is as
parenthesis well, one of the most delightful persons. He and his wife are a charming
couple with a fine young son.) He is an accomplished musician, and shares
his talent by singing in the best church choir in town. At
Christmastime, he sang (with the choir) The Gloria by Poulenc. (I can
think of no young person with whom I would rather be associated.)
I am sure he will be a very satisfactory member of your faculty.

Sincerely,

David J. Rogers
Professor of Biology

DJR/pch



Long Island University

C. W. POST CENTER

Greenvale, New York 11548

Telephone 516-299-2481

Faculty position ^{for} ~~about~~ which you requested my comments

April 7, 1980

C.W. Post College of Arts & Sciences
Department of Biology

Dr. David J. Rogers
Professor of Biology
Dept. of E.P.O. Biology
Hale 114, Box 334
Boulder, Colorado 80309

Dear Dr. Rogers:

Mr. Barry Johnston has given your name as
a reference regarding a faculty position at
C.W. Post College. We would appreciate your
providing us with your frank opinion of this
candidate's qualifications.

Thank you for your cooperation.

Cordially yours,

Margaret S. Hertz

Margaret S. Hertz
Chairman
Department of Biology

MSH:aj

8 February 1980

Dr. John N. Owens
Chairman Selection Committee
Department of Biology
University of Victoria
P.O. Box 1700
Victoria, British Columbia V8W 2Y2
Canada

Dear Dr. Owens:

It gives me great pleasure to recommend Barry Johnston for the position in Plant Taxonomy in your Department. Barry is eminently well qualified for the position as you describe it. I taught him a course in Flowering Plant Taxonomy, emphasizing comparative morphology and anatomy of the families, along with practicals in selected samples of the more critical families. He was an outstanding student therein. Since then, he has been a teaching assistant in plant taxonomy, and so has had experience both as a student and as a teacher of the subject. Barry has also been a teaching assistant in general biology, and is therefore well qualified in that area.

Barry has been an herbarium assistant under Dr. William Weber, and was given outstanding training in curatorial activities. I am certain that you know the reputation of the Herbarium here, as one of the "national resources" of the U.S., a tribute to Dr. Weber's outstanding efforts to make this one of the best, well-rounded medium-size herbaria of the country. Barry has been responsible for much of the computerized data processing for the herbarium. He wrote several programs and routines for multiple entry keys, for label data processing, for input to our computerized information and storage retrieval system known as TAXIR (or EXIR), and several other important processing methods that help make the record-keeping process of the herbarium more up-to-date than nearly any other herbarium I know about.

Barry has taken my course work in taximetrics, and was so good that I invited him to give some lectures on the subject, including comparisons of clustering methods available for taximetric work. His theoretical knowledge of math, computing, and taxonomy provide him with one of the soundest modern taxonomic backgrounds possible to achieve anywhere in this country.

In addition to the above-mentioned skills, Barry knows his plants. He has done extensive field work throughout the Rocky Mountains, has collected plants in Chile, collected and observed plants in Nigeria, and has a remarkable general knowledge of plant ecology, geography, and population dynamics. He is recognized as one of the experts on the rare

Dr. John N. Owens
8 February 1980
Page 2

and endangered species of Colorado. I have insisted that his thesis be monographic in style, because I feel that such type of effort forces a greater perception of problems of speciation, and the relation between formal taxonomic structure and the dynamics of population structure. His work on the genus Potentilla is one of the best designed and carried-out studies I have had the pleasure to see in any graduate student.

Barry is well-acquainted with the formalities of nomenclature, as well as historical aspects of plant taxonomy. His knowledge is sufficient to provide guidance to many other students, with whom he is most willing to share his expertise. This implies, and I find it true, that he is well thought of by his peers.

With all of the above, Barry is no drudge—he has a wide range of interests and abilities. He is a very good pianist, and a good singer, he has participated in the best church choir in Boulder, which is composed mostly of professional musicians. Barry and his wife are good hosts, and it is a pleasure to spend an evening with them. His outstanding training and experience, his friendly personality, his interest in students, and his research, make him, in my opinion, an outstanding candidate for the position in your Department.

Sincerely yours,

David J. Rogers
Professor of Biology

DJR/pch



UNIVERSITY OF VICTORIA

P.O. BOX 1700, VICTORIA, BRITISH COLUMBIA, CANADA V8W 2Y2
TELEPHONE (604) 477-6911, TELEX 049-7222

Department of Biology

January 30, 1980

Dr. David J. Rogers
Department of E.P.O. Biology
Hale 114, Box 334
Boulder, Colorado 80309
U.S.A.

Dear Dr. Rogers:

Barry Johnson has applied for a position in Plant Taxonomy in this Department and has submitted your name as a referee.

Responsibilities of the position include teaching Plant Taxonomy, Introductory Biology and contributing to our second year course in Metaphyta. The appointee would also serve as curator of the herbarium. Productive research in Plant Taxonomy is essential and active participation in Departmental and University Affairs is expected.

We would appreciate your candid evaluation of Mr. Johnson as a potential appointee to this position. In particular, we are concerned with the appointee's ability to teach at the elementary as well as the advanced level and to carry out productive research. Your comments will be treated in strict confidence.

Sincerely,

John N. Owens
Chairman Selection Committee

JNO:pm

The DEPARTMENT OF BIOLOGY at Kenyon College announces a tenure-track position, with rank and salary open. Responsibility will be for a nonmajors course in biology, participation in general biology, and teaching an upper-level course in the person's specialty. Preference will be given to those with training in environmental and/or population biology. Ph.D. required, research opportunities available. Send letter of application, curriculum vitae, transcripts, and three letters of recommendation to: Search Committee, Department of Biology, Kenyon College, Gambier, Ohio 43022. An Equal Opportunity Employer. Closing date: 15 January 1980.

Affirmative Action Employer

FACULTY POSITIONS

Ph.D.'s invited to apply for two tenure-track faculty positions in the Biology Department. (i) **INVERTEBRATE** biology with ability to offer ecology/evolutionary studies; some competence in environmental geology is desirable. (ii) **BOTANIST**, introductory geology is desirable. Additional required background in horticulture. Additional requirements: understanding of and long-term commitment to quality teaching within a liberal arts format; willingness to initiate direct undergraduate research. Send curriculum vitae and three letters of reference to: William Laughner, Biology Department, Hiram College, Hiram, Ohio 44234, by 15 January 1980. Hiram College is an Affirmative Action/Equal Opportunity Employer.

MACROMOLECULE CRYSTALLOGRAPHY

Resource director for GRIP Molecular Graphics Research Resource. Must have Ph.D., experience in search, Resource. Must have Ph.D., experience in crystallographic computations and/or computer graphics. Will be responsible for liaison with using biochemists and coordination of development of our next-generation molecular graphics system. Full-time research faculty appointment. Professor F. P. Brooks, Jr., Department of Computer Science, New West Hall 035A, University of North Carolina, Chapel Hill, N.C. 27514. Affirmative Action/Equal Opportunity Employer.

Affirmative Action Employer

ASSISTANT PROFESSOR, BOTANY

The Department of Biology, Vassar College, invites applications for a tenure-track position beginning in 1980-1981. Expertise in organismal and evolutionary botany. Teaching areas will include intermediate and advanced undergraduate courses in botanical sciences as well as participation in the departmental introductory course. Applicant will be expected to conduct research in the botanical sciences. Departmental resources include greenhouses, herbarium, and 250-acre ecological preserve with on-site field laboratory. Send letter of application, resume, and three letters of reference to: Dr. Patricia Johnson, Chairman, Box 377, Department of Biology, Vassar College, Poughkeepsie, New York 12601.

Vassar College is an Affirmative Action/Equal Opportunity Employer.

January 1980

CURRICULUM VITAE

Barry C. Johnston

Barry Cummins Johnston
1300 30th Street, Apt. E4-11
Boulder, Colorado 80303
U. S. A.

Telephone numbers:

University: (303) 492-7187
Home: (303) 444-6927

Born: Los Angeles, California
November 15, 1943

Present Age: 36 years

Citizen of United States of America (Social Security No. 523-58-8380)

Married to Joanne (Moynihan) Johnston for 3 years; one son, Jeffrey Johnston, aged 6 months

Education

Attended public schools in Durango, Colorado; graduated from Durango High School second of 160 students, in 1961.

Attended University of Colorado 1961-1966 with benefit of Colorado State Regents Scholarship. Student of Electrical Engineering, 1961-1963, while part of Superior Student Program, College of Engineering. Student of Engineering Physics, 1963-1966. B. S. (Engineering Physics), 1966.

Attended University of Colorado 1971-1973 and 1976-1980, graduate student in Ph. D. program; Major Advisor: Dr. David J. Rogers, Professor of Biology, Department of Environmental, Population, and Organismic Biology. Fields of study: taxonomic botany, especially aided by numerical methods; population genetics and population statistics of higher plants; evolution of higher plants; and field and herbarium techniques in plant taxonomy. Expected to receive Ph. D. in June or August 1980.

Thesis topic: Variation and systematics of *Potentilla* sect. *Multijugae* (Rosaceae), as shown by population statistics. Data from many population samples, and from herbarium specimens. Techniques: character analysis and single-linkage clustering; population statistics.

Employment and Other Experience

- | | |
|-------------|--|
| Summer 1963 | Road surveyor, U. S. Forest Service, San Juan National Forest. Used compass, level, trigonometric calculations. |
| Summer 1964 | Research assistant, University of Colorado, Department of Electrical Engineering. Detection of ferroelectric properties of salt crystals. |
| 1964-1965 | Research assistant, University of Colorado, Department of Electrical Engineering. Calculation of properties of guided microwaves. |
| 1967-1970 | Volunteer teacher, U. S. Peace Corps, Kaduna, Nigeria. Taught at Kaduna Polytechnic, an engineering college; taught mathematics and physics, mainly college calculus and first year physics laboratory, but also a wide variety of other mathematics courses at levels from secondary school through third-year college. Organized and managed large school library. |

- 1971 High school teacher, Lemoore Union High School, Lemoore, California. Taught high school geometry and algebra (ninth and tenth grades).
- 1971-1973 Personal research on field botany in mountains of Central Colorado.
- 1973-1974 Technician, Solid State Electronics, Boulder, Colorado. Installed and repaired automobile radios and tape players; part-time manager of this small business.
- 1974-1975 Personal research, plants of southwestern Colorado. Spent considerable time in the mountains of south-central and south-western Colorado, doing field botany, especially phenology and pollination mechanisms.
- 1976-1979 Research assistant in Botany, University of Colorado Museum, Boulder, Colorado. Used herbarium and field botanical techniques, and floristic research, under Dr. William A. Weber, Curator of the Herbarium (COLO). Participated in active program of research into the Flora of Colorado. Investigated computer methods of museum cataloging, and preparation of polyclave (punch-card) field keys. Wrote computer programs to produce herbarium specimen labels automatically.
- 1976 Botanist, U. S. Forest Service, Southwestern Region, Albuquerque, New Mexico. Did field surveys, literature and herbarium research on populations of proposed Threatened and Endangered Plant species, in Arizona and New Mexico.
- 1977-1979 Botanist, U. S. Forest Service, Rocky Mountain Region, Lakewood, Colorado. Did field surveys, literature and herbarium research, on populations of proposed Threatened and Endangered plant species, in Colorado and Wyoming. Did similar studies on a large number of plant species of local interest. Participated in several range-management training sessions for field personnel, as teacher of plant identification techniques.
- 1979 Teaching Assistant, Department of E. P. O. Biology, University of Colorado, Boulder, Colorado. Was responsible for introducing and teaching several sections of General Biology (Freshman) laboratory per week. Was also responsible for teaching Classification of Flowering Plants (Junior) laboratory: organizing and presenting introduction to several families of flowering plants per week, obtaining and preparing plant material for study and dissection, and conducting laboratory. Wrote and graded laboratory examinations.

Publications

- Weber, William A. & Barry C. Johnston (1976). Natural History Inventory of Colorado. I. Vascular Plants, Lichens, and Bryophytes. University of Colorado Museum, Boulder.
- Weber, William A., Barry C. Johnston, & Dieter Wilken (1979). Additions to the flora of Colorado. VI. *Phytologia* 41:486-500.
- Johnston, Barry C. (1979). Proposed and recommended threatened and endangered plant species of the Forest Service Rocky Mountain Region: an illustrated guide. U. S. Forest Service, Lakewood, Colorado.

Weber, William A. & Barry C. Johnston (1979). Natural History Inventory of Colorado. I. Vascular Plants, Lichens, and Bryophytes, second edition. University of Colorado Museum, Boulder.

Johnston, Barry C. (1980). Computer programs for constructing polyclave keys from taxonomic data matrices. Taxon, in press.

Other Activities

Mountaineering; mountain rescue

Geography and field geology of southwestern U. S.

Field Botany, especially of Colorado, Wyoming, New Mexico, Arizona, and Utah

Ski-touring

Classical, baroque, and romantic music; popular music of the 20s and 30s

Plays piano, sings vocal music (baritone)

Active church member

Photography, especially field photography of plants

Household repair, especially carpentry and painting

Short-wave radio listening

Membership

Colorado Native Plant Society

Southwestern Association of Naturalists

American Society of Plant Taxonomists

National Geographic Society

Languages

Reads and writes Russian; translation of scientific articles

Reads German (fair)

Reads botanical Latin (fair)

Speaks Hausa

Research Interests

1. Taxonomic and floristic botany, especially of vascular plants, with special interest in their biogeography. To date I have focused on both field and herbarium-library methods, and have dealt with plants of Colorado, New Mexico, Arizona, and Wyoming, but I plan to become involved in the flora of any region into which I may move.

2. Variation within and among plant populations, especially statistical, and particularly in what way that variation facilitates classification into taxonomic categories. I have mainly worked with herbaceous perennials of plains grassland, montane meadows, alpine meadows, and talus slopes; in the genera Machaeranthera (Compositae) and Potentilla (Rosaceae).

3. Population statistics of rare endemic and wide-disjunct plant species, mostly proposed threatened or endangered species. Detection and study of the factors leading to change in small populations. I have worked with species of many different communities, with an emphasis on those of high-alpine rocky ridges and talus slopes.

4. Revision of the species of Potentilla (Rosaceae) in North America. Taxonomy, biogeography, and breeding mode of other genera in this family.

5. Computer methods in plant taxonomy, especially:

a. Programs for analysis of characters to be used in classification, particularly CHARANAL, developed by David J. Rogers and others at the University of Colorado.

b. Programs to aid identification, especially polyclave (punch-card) keys for field use. I have produced and developed a set of programs to produce such keys, using methods of William A. Weber and others at the University of Colorado Museum.

c. Programs for clustering taxonomic units, particularly the single-linkage clustering program GRAPH, developed by David J. Rogers and others at the University of Colorado.

d. Programs for automatic production of herbarium-specimen labels. I have written and developed a set of such programs that is now in use at the University of Colorado Museum, and will be adapted for use in at least one other herbarium.

e. Computer production of taxon descriptions and dichotomous keys for floras.

6. Computer methods in plant ecology, especially ordination.

7. Population ecology of weeds and species that increase with grazing pressure.

8. Taxonomy and ecology of economic plants.

Exp. field botany - from youth -
(in addition to engineering/physics)

Genl. biol. background.

(essentially a 2nd undergrad. bio. maj. -
genetics, physical, class fl. pl.
biometry, pop. genetics.
biocytonics (A. Love).

Mathematics (all sorts) Prob. theory, statistics
2 courses in computer programming -
ME, E.E.

Physics - quantum mechanics.

Competent designer of programs -

Independent field botany of the west,
in 1972.

TA for EPOB (genl. bio.).

Variation and Systematics of Potentilla sect. Multijugae

I. Taxonomy and Morphology

Potentilla is in the family Rosaceae, subfamily Rosoideae, tribe Potentilleae. In the sense of its latest monographer (Wolf 1908), the genus Potentilla contains all the species of this tribe that have 10-indefinite stamens attached near the base of the carpophore; this carpophore does not become conspicuously fleshy in fruit (as in Fragaria). This is the broad sense most often used in Europe and America.

Rydberg (1898, 1908), the leading American systematist of the genus, distinguished several genera that had been included in Potentilla by Wolf and his predecessors. These are Argentina (A. anserina); Comarum (C. palustre); Drymocallis (D. glandulosa, D. fissa, etc.); Pentaphylloides (P. fruticosa, P. floribunda, etc.); and Sibbaldiopsis (S. tridentata).

Pentaphylloides and Sibbaldiopsis are shrubs or subshrubs with hairy achenes and styles attached basally to the achene. For a discussion see Löve (1954). Drymocallis are large plants with large, pinnate leaves, and basal styles. Argentina has lateral styles and interruptedly-pinnate, bicolored leaves; the plants are often stoloniferous. Argentina has a chemistry that is unique in the Rosaceae (Bate-Smith 1962). Comarum has large, red flowers, lateral styles, inhabits bogs, and has a receptacle becoming somewhat spongy in fruit.

Pentaphylloides is monoecious or functionally semi-dioecious. Pentaphylloides, Sibbaldiopsis, and Drymocallis are predominantly diploid ($2n = 14 = 2x$, where $x = 7$) with rare tetraploid or hexaploid populations (Calusen et al. 1940). Argentina is predominantly tetraploid with rare hexaploid populations (Rousi 1965). Comarum has been reported to have tetraploid and hexaploid plants.

The closely-related genus Fragaria differs from Potentilla only in its fleshy carpophore, yet in Fragaria no apospory or parthenogenesis has been reported; these phenomena are widespread and common in Potentilla s.str. (Rutishauser 1943). Excluding vegetative reproduction, Drymocallis, Pentaphylloides, and Argentina are (as far as known) completely sexual (Fryxell 1957), similarly to Fragaria. Several successful crosses have been made between Fragaria as ♀ parent, and Pentaphylloides, Comarum, and Drymocallis ♂♂. But no crosses have yet been successful between Fragaria and Potentilla s.str. (Asker 1969).

Rydberg (1898) divides Potentilla into 21 "groups". These are probably equivalent to "sections", since they are the only taxonomic level used between the genus and its species, and Rydberg uses the paragraph symbol (§) to refer to them, as was common for sections in his day. They were all given a short description. Combining his

description with his key, and with those in Wolf (1908):

Potentilla L. sect. Multijugae Rydberg (1908). Perennial herbs from a shortly-branched woody root; stem ascending, erect, or often prostrate, usually less than 3 dm long; radical leaves sub-pinnate to more often conspicuously pinnate, with 3-13 pairs of leaflets, which are coarsely toothed; leaves hirsute to strigose, rarely also with tomentum, sometimes also glandular, never bicolored; inflorescence usually many-flowered with conspicuous pedicels, not conspicuously leafy; receptacle short-hairy; petals 5-10 mm long, yellow, emarginate; stamens 25-30; achenes glabrous, shining, 1.0-1.8 mm long; styles terminal, thickened just above the base, slender, long-protruded and filiform, 2-3 times as long as the achene.

There are about 30 named taxa in this section (Table 1B). Of these, nine are considered by most authors of recent floras to represent valid species (Kearney & Peebles 1951, Munz & Keck 1959, Hitchcock 1961, Holmgren & Reveal 1966, Dorn 1977).

1. Potentilla breweri S. Wats. (var. expansa S. Wats., var. viridis Jepson, P. plattensis var. leucophylla Greene, P. versicolor Rydb.). Mountains of central and northern California, ranges of northern Nevada, and southeastern Oregon. This species was not included in Multijugae by either Rydberg or Wolf, yet it has obvious affinities to it (Clausen et al. 1940). P. breweri is usually distinguished by the presence of tomentum and its distinctive leaf-form: with ultimate segments greater than 1.5 mm wide. In SE Oregon (Steens Mts.) P. breweri merges with P. ovina in adjacent populations, as shown by the notes on the specimen Cronquist 8699 (NY).

2. P. candicans Humb. & Bonpl. (var. crocea Lehm., var. nana H.B., P. ancistrifolia Galeotti?). Mountains of central Mexico. Seems amply distinct with its narrow, linear segments and silvery-yellowish pubescence; probably related to P. ovina.

3. P. crinita A. Gray. (Ivesia lemmonii S. Wats.). Northern Arizona and New Mexico; southern Colorado, Utah, and Nevada. Narrow, linear leaflets with usually only 3 teeth at the very tip; leaflets sericeous and distinctly curved in an arc. Several specimens from southern Utah are difficult to determine due to their proximity to pinnate forms of P. concinna; generally, however, this species is easily distinguished.

4. P. drummondii Lehm. (ssp. bruceae (Rydb.) Keck, P. cascadiensis Rydb., P. anomalifolia Peck). Northern California in the Cascades north through Oregon and Washington to southern British Columbia and southeastern Alberta. Tall plants with erect-ascending stems and large, dissected, broad leaflets. Closely related to P. breweri; usually distinguished by the lack of tomentum (Clausen et al. 1940), but apparently hybridizing with P. breweri where sympatric in SE Oregon (Hitchcock 1961).

5. P. hickmanii Eastwood. San Francisco area, California; rare, in fresh-water marshes. Distinguished from P. millefolia by its 4-6 pairs of leaflets and often more ascending growth.

6. P. millefolia Rydb. (var. algida Jeps., var. densa Jeps., P. klamathensis Rydb.). Northern California and Nevada; south-central Oregon. Usually prostrate, with 6-12 pairs of leaflets; differs from P. plattensis in its narrower leaflets, although

occupying the same habitats; moist meadows of mountain valleys and foothills.

7. P. multijuga Lehm. Coastal plain near Los Angeles, California; probably extinct. Tall, with leaves toothed only, not divided.

8. P. ovina J. M. Macoun. (P. dissecta var. decurrens S. Wats., P. diversifolia var. pinnatisecta S. Wats., P. monidensis A. Nels., P. nelsoniana Rydb., P. wyomingensis A. Nels.). Usually alpine, often in soil derived from calcareous rock. The most distinct form has divided-cespitose root, leaflets deeply dissected and tending to have erect leaves; and stems prostrate-creeping with few flowers. However, the forms with fewer, less-dissected leaflets and less prostrate habit have been confused with two other species. In the alpine, especially in Utah and Colorado, occur forms that are difficult to distinguish from P. diversifolia, especially P. diversifolia var. decurrens and var. multisecta. There are some lowland or medium-elevation forms of P. ovina in central Wyoming and eastern Idaho that look very much like P. plattensis (see Map 1A). The Alaska specimen needs to be compared with Asiatic species.

9. P. plattensis Nutt. (var. pedicellata A. Nels.). Meadows of foothills and mountain valleys, southern Saskatchewan and SW Manitoba, western N Dakota and S Dakota, eastern Montana and Wyoming, eastern and central Colorado, central New Mexico and Arizona. It is difficult to decide whether lowland forms in Utah are this species, P. ovina, or P. diversifolia.

II. Chromosome numbers and reproduction

<u>Species</u>	<u>2n</u>	<u>Reference</u>
<u>P. breweri</u>	72-73, 99, 100, 102	Clausen et al. 1940
<u>P. crinita</u>	84	Shimotomai 1930
<u>P. drummondii</u>	64-108 105	Clausen et al. 1940 Popoff 1939
<u>P. diversifolia</u>	82-84, 91, 101 42	Clausen et al. 1940 Gustafsson 1947

Table 2. Chromosome numbers in Potentilla sect. Multijugae, and in P. diversifolia. No reports for P. candicans, P. millefolia, P. multijuga, P. ovina, or P. plattensis.

P. diversifolia is included here because of its apparent affinity with P. ovina and P. plattensis. It was included in the P. gracilis complex by Clausen et al. (1940), where it "stands out sharply". They commented on the similarities between P. drummondii and P. breweri on one hand, and P. diversifolia on the other, in morphology, high chromosome numbers, floral structure, response to uniform-garden experiments, and variation of chromosome number within populations.

Meiosis is highly irregular in the only members of this section that have been studied (P. drummondii, P. breweri, P. diversifolia); the chromosomes are very small, and pollen is irregular in size.

In many other sections of Potentilla, high chromosome number is often an indicator of apomictic reproduction; some workers believe that apomixis facilitates the maintenance of higher ploidy levels. In Potentilla, apomixis is usually apospory followed by parthenogenesis; this usually requires pseudogamy, so that pollen usually needs to be present for development of fruit (Rutishauser 1948).

As far as known, no one has studied barriers to hybridization in this genus, although the presence of pollen nuclei in the embryo-sac during pseudogamy doubtless makes hybridization easier.

My personal observation is that individual populations of Potentilla tend to be rather uniform, but often with evident morphological characters separating them from populations in other areas. This would indicate that these populations reproduce largely apomictically; nonetheless, there is some sexual reproduction, as reported by Clausen et al. (1940) in populations of P. drummondii, P. breweri, and P. diversifolia.

III. Materials and Methods

As many herbarium specimens as possible of this section will be examined; those from NY, GH, UTC, BRY, RM, and COLO are now being worked on. Many specimens, however, diverge from each other in a multidimensional fashion, seriously limiting any analysis of them based on a few characters.

The characters that have most often been used in morphological classification within Potentilla are:

1. Style insertion. Used for generic classification by Rydberg, and sectional classification by Wolf. Probably does not vary in this section.
2. Style form. Used for sectional classification by Wolf, and for species (often incorrectly drawn or measured) by Rydberg. Style shape is probably constant in this section, but style length probably has some value; P. diversifolia often has a style over 3.0 mm long, for example.
3. Leaf division. Used as a "unit character" by Rydberg (i.e., leaves either pinnate or digitate, with no middle ground allowed), used as an important character by Wolf but allowed some states between pinnate and digitate. Most populations tend to be constant in the degree of pinnateness (as measured by per cent of rachis occupied by leaflets). Certain species are also constant in this character; the problem arises in detecting which ones are constant and which are variable, for example, P. diversifolia.
4. Number of leaflets. Probably $\pm$ correlated with leaf division; used to divide certain pinnate species, as P. millefolia and P. hickmani.
5. Division of leaflets: whether pedate, pinnate; how many divisions; how deep; shape and width of segments. This is sometimes used as a secondary character, but tends to be variable between populations; probably has not been consistently surveyed.

6. Pubescence: whether strigose, sericeous, tomentose, glandular, etc.; relative thickness and distribution. Used for divisions of the genus by Wolf, which has been criticized by Clausen et al. (1940); as a secondary character by Rydberg. It probably is less important than either of these workers thought. Many populations are variable, especially in degree of tomentose pubescence. This character is probably most important on leaf surfaces, petioles, and calyx.

7. Petal length, particularly in relation to calyx lobes, and petal shape. These are probably not variable in this section.

8. Number of stamens. Probably not variable in this section.

9. Stamen size. Used by Hitchcock (1961) to separate species.

10. Calyx size. This, as an indicator of flower size, might have some value: P. plattensis and P. millefolia usually have larger flowers than some other species of this section.

11. Stipule size and division. Has not been carefully surveyed, however probably does not vary in this section.

From the above discussion of characters, one can see the use of these characters in previous taxonomic classifications. These classifications, however (especially that of Rydberg 1908), have been unsuccessful to one degree or another. In order to provide the basis for a more successful classification in this section, in which apomixis is strongly expected, the relative value of characters must be estimated; no previous workers have quantified (or recorded, except in a very general, qualitative way) the variation of characters within populations or between adjacent ones. Since these ideas are based on the hypothesis of populations with largely apomictic reproduction and an occasional sexual hybridization event, data must be measured showing the occurrence and proximity of other species (even of other sections of the genus) to the population. Two kinds of approach to the problems of analysis of characters will be taken.

I propose to sample populations of species of this section, using about ten characters; two kinds of sample-structure will be used, a square plot (adjusted to include about 25 individual plants of the species in question) for the middle of homogeneous populations, and a transect for long ridges and boundaries between populations. I intend to estimate chromosome number in a rough way by collecting samples of pollen from each plant (see Kohli & Packer 1976); root-tips and/or buds will be fixed from selected individuals as a control on the expected relationship between chromosome number and pollen size.

From these populations sampled, herbarium specimens will be taken of selected individuals as vouchers; a leaf will be collected and dried from selected individuals for analysis by paper chromatography of flavonoids.

The data collected from these population samples will then be used to calculate correlation coefficients between pairs of all characters used, including the pollen measurements and chromatographic data. Appropriate statistical techniques will be used, to try to deduce which characters vary within populations, and which vary within larger population clusters.

I would like to sample as many populations as possible within the time allowed; priority will be given, however, to populations known to be critical between taxa. For each population sampled, the spatial relationship to other species of Potentilla will be estimated, and those other species sampled.

Another approach to the analysis of characters is proposed for herbarium specimens: the information-theoretic computer program CHARANAL (e.g., Bisby 19). This program estimates the information contained in each character, and thus is an aid in structuring characters for classification.

It will probably not be possible to sample every species in this section; I propose to concentrate on the P. ovina problem, for the scope of population samples. Here, the questions to be answered involve the relationships between P. ovina on one hand, and P. breweri, P. diversifolia, or P. plattensis on the other.

However, I propose to also include a classification of this section of Potentilla, and to describe the relationships of this section to other sections. To aid in this classification, I will use data from herbarium specimens (aided in the selection of characters by the character-analysis experiments described above) as input to a nearest-neighbor single-linkage clustering scheme called GRAPH (Estabrook 19 , Bisby 19). This clustering procedure has in several cases performed better than either principal components analysis or other clustering methods.

The chromatographic data will also be subjected to clustering by the same procedure (Asker & Frøst 1970).

Table 1B.

Potentilla sect. Multijugae Rydb., Mem. Dept. Bot. Columbia Univ.
2:30-31 (1898)

- P. ancistrifolia Galeotti
- P. arizonica Greene
- > P. breweri S. Wats.
var. expansa S. Wats.
- > P. candicans H.B.
var. crocea Lehm.
var. nana H.B.
- P. cascadiensis Rydb.
- > P. crinita A. Gray
var. lemmonii (S. Wats.) Kearn. & Peeb.
- P. decurrens (S. Wats.) Rydb.
- > P. dissecta Pursh var. decurrens S. Wats.
- > P. diversifolia Lehm. var. pinnatisecta S. Wats.
- > P. drummondii Lehm.
- > P. hickmanii Eastw.
- P. humboldtiana Tratt.
- P. lemmonii (S. Wats.) Greene
- P. lineariloba Ser.
- P. klamathensis Rydb.
- > P. millefolia Rydb.
- P. monidensis A. Nels.
- P. multijuga Lehm.
- P. nelsoniana Rydb.
- > P. ovina J. M. Macoun
- > P. pinnatisecta A. Nels.
- > P. plattensis Nutt.
var. leucophylla Greene
var. pedicellata A. Nels.
- P. richardii Lehm.
- P. versicolor Rydb.
- > P. wyomingensis A. Nels.

Ivesia lemmonii S. Wats.
Ivesia pinnatifida S. Wats.

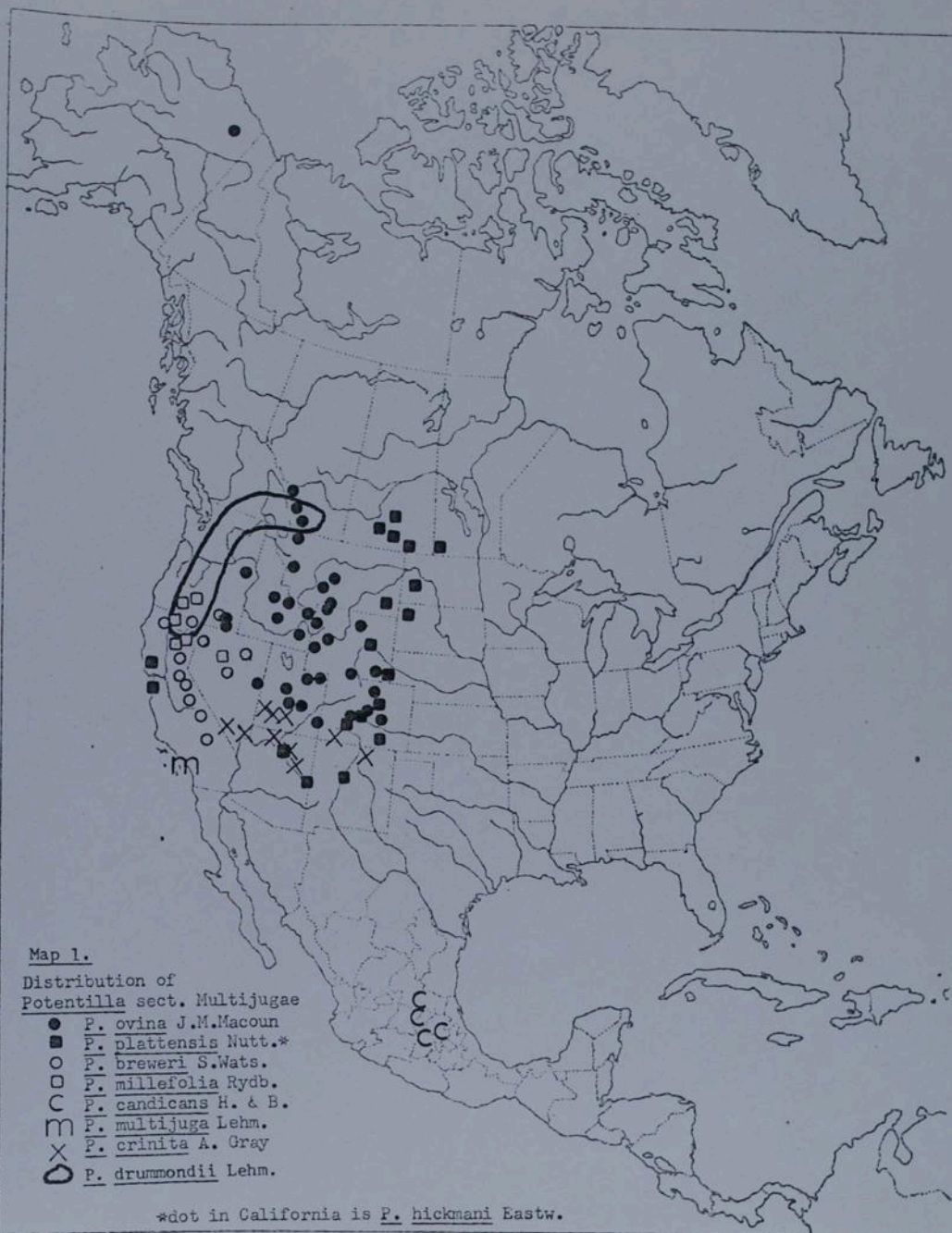


Table 1A.

Potentilla, group related to P. diversifolia Lehm.

P. decurrens (S. Wats.) Rydb.

P. dissecta Pursh

var. decurrens S. Wats.

var. glaucophylla (Lehm.) S. Wats.

var. multisecta S. Wats.

P. diversifolia Lehm.

var. glaucopylla Lehm.

var. multisecta S. Wats.

ssp. ranunculus (Lange) A. E. Porsild

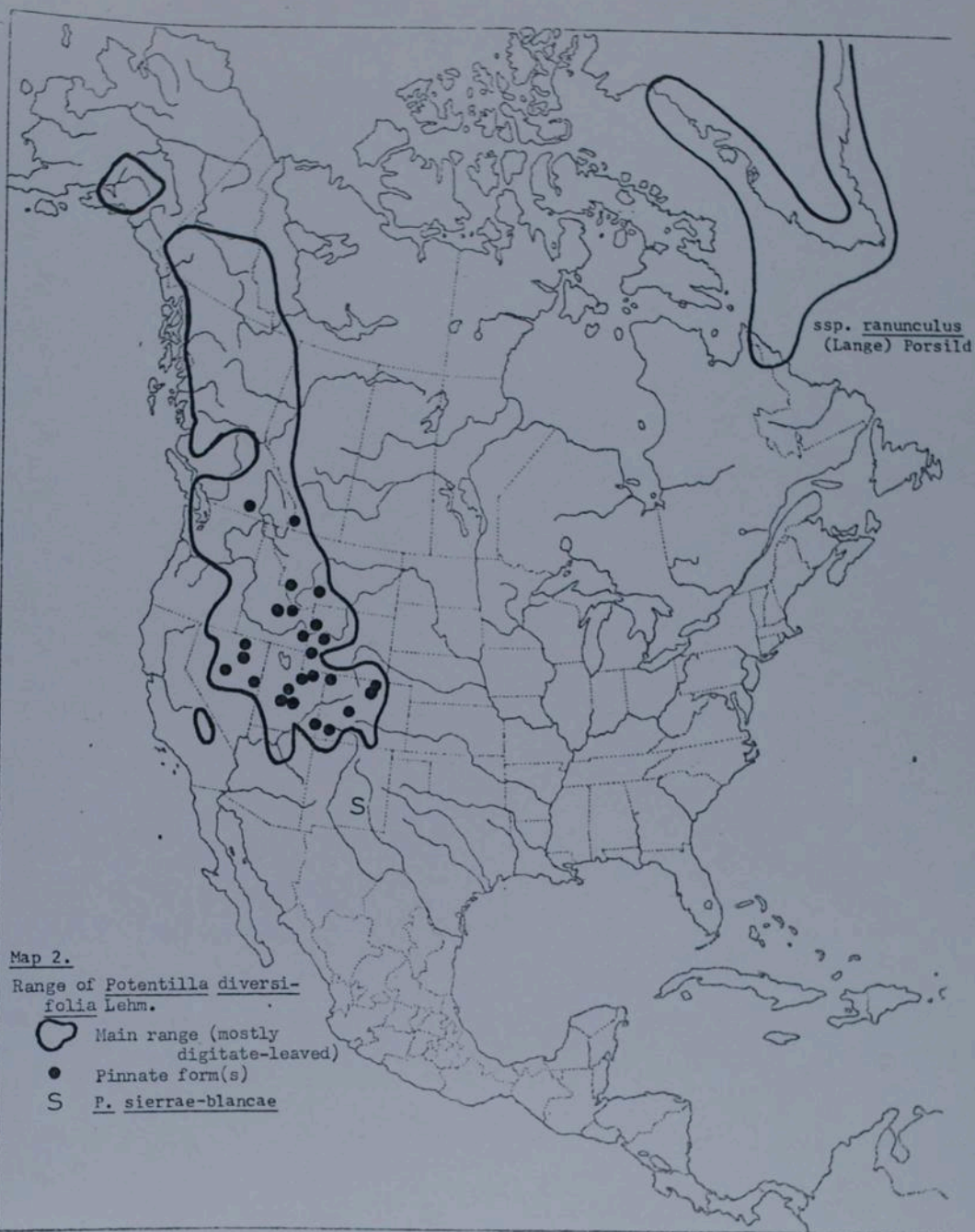
P. macrorrhiza Willd.

P. multisecta (S. Wats.) Rydb.

P. ranunculus Lange

P. sierrae-blancae Wootton & Rydb.

P. vreelandii Rydb.



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November 22, 1979

To: Professors Bye, Grant, Marr, Quick, Rogers, and W. Weber

From: Barry C. Johnston

Regarding: Ph. D. Comprehensive

Enclosed is the thesis proposal for your inspection. Please accept my apology for its lateness: my case of flu which won't go away, and the snowstorm which closed the University for a time are offered as reasons, but not excuses.

As you know, the Comprehensive has been scheduled for Thursday morning, November 29, 1979, at 8:30 A.M., in Hale Building, room 109.

Thank you very much for your help and cooperation.

Variation and Systematics in Potentilla sect. Multijugae

A Thesis Proposal, prepared for the
Ph. D. Comprehensive Examination, by
Barry C. Johnston
November 22, 1979

1. Introduction

Analysis of the structure of populations and the variation within and among them is the basis for classification of the organisms. This is so because the concepts of species, subspecies, genus, and so on are best seen as clusters of populations. An important part of classification is selection of characters and their states that will partition a group of populations into meaningful clusters. The characters used in classification are often morphological ones, for comparative morphology is the tool and herbarium specimens the materials must often and abundantly available to taxonomists.

Therefore, it is important to relate the morphological characters used to construct the classification, with the variation of those characters within and among populations.

The genus Potentilla (Rosaceae—Rosoideae—Potentillinae) is appropriate for a thesis study, because its classification is confused: the various recent schemes that have been proposed are markedly different. This genus contains a number of problems; the taxonomic confusion and the population problems are well illustrated by the section Multijugae, which is geographically restricted to western North America (with one species disjunct in central Mexico), with its center of distribution in the southern and central Rocky Mountains. When the space and time limitations of the thesis are considered, this section immediately becomes apparent as one in which population studies can be made.

The classification schemes that have been proposed for sect. Multijugae show use of a variety of characters, no one of which seems to be capable of classifying populations into higher categories. There is a need for revision of the section, based on comparisons among more than a few characters; these comparisons are difficult using traditional taxonomic methods, since the human mind is usually incapable of analyzing more than two or three characters over anything but a very small suite of items. Particularly is this multi-character approach necessary, since the complexity of the problem within

Potentilla probably derives from the tendency of many species to reproduce apomictically, with interspecific hybridization comparatively frequent, and high chromosome numbers that may vary widely within a population.

It is proposed to estimate the components of variance within each of a number of populations in sect. *Multijugae*, for each of a large number of characters. These, together with estimates of correlation between pairs of characters, will be used to indicate which characters might be useful in the later classification phase of this study. Between populations, a large set of herbarium specimens (including "exemplars" of the sampled populations) will then be subjected to character analysis, which will lead to further refinement in the set of possible characters for the classification.

A large set of herbarium specimens will then be classified, using the refined characters deduced from the inter- and intra-population studies above, and using a technique which allows comparison of a large set of characters in calculating a similarity measure.

Potential results will include a revision of sect. *Multijugae*, showing in what way(s) past classification schemes are correct, and in what way(s) they are incorrect; and an evaluation of the proposed method, that is, the use of population samples as an aid in classification using a clustering procedure. Such work may also point the way to solution of the classification problems in other sections of the genus.

2. Population Studies in Taxonomy

In its modern, restricted sense, population means "the community of potentially interbreeding individuals at a given locality...[that] share in a single gene pool...by definition a panmictic (randomly interbreeding) unit" (Mayr 1970, p. 82). This definition is obviously applicable only to individuals that are in the habit of crossing with each other in a local area; asexual reproduction, such as gametophytic apomixis, as is common in many plant groups (Fryxell 1957, Grant 1971, etc.), renders the definition nearly unworkable. Plants in which there is a large proportion of inbreeding may also cause the definition to become unworkable, although in this case there are often small clusters of individuals at a locality that can be detected morphologically or biochemically (Allard & Kannenberg 1968; Allard, Jain, & Workman 1968).

The presence of the word "potentially" in Mayr's definition of population cited above would seem at first glance to make the definition applicable to a wider range of organisms, but in fact the definition is only made more obscure thereby, since it is not clear which barriers to reproduction may be included within a population, and which are excluded. Particularly this point is important in plants, where there are many examples of the plants of a species in a local area, divided into populations by edaphic, topographic, or ethological barriers (Levin 1978). The phrase "potentially interbreeding" was originally included in the famous definition of species given by Mayr in 1963; however, Mayr himself apparently dropped the phrase from the definition of species after about 1969 (Mayr 1970, p. 12; Sneath & Sokal 1973, p. 364).

These difficulties with the definition of population have been approached in several ways. The most common way of attempting a solution is to restrict the discussion of populations to sexual, outcrossing forms (e.g., Mettler & Gregg 1969, pp. 26, 30); this approach does not really solve the problem. A more satisfying, albeit less biological, method is to define population

operationally: "any group of individuals considered together at any one time because of features they have in common" (Davis & Heywood 1963, p. 353). This is a more practical definition, especially since breeding relationships of individuals are difficult to measure and assess; the operational definition of population also suggests the use of morphological characters, as Davis & Heywood point out (1963, p. 355), and allow more direct sampling techniques, rather than progeny, biochemical, or breeding studies. This practical definition will be used in this study, except that it will be restricted to those plants which appear to form a coherent local unit. In other words, an estimate will be made of a population as if it were a breeding unit, without performing the genetic studies necessary to establish population size.

The morphological, operational definition of population seems to be more appropriate when the relationship of the population made up of individuals, to the species made up of populations, is considered. The simplest case is that of a species with only one population, which is exceptional; most species have many populations. The species is the taxonomic level of greatest concern and controversy, the central, fundamental level of systematic focus and also of the nomenclatural hierarchy. The species concept cannot be precisely defined in such a way that fits every case; however, most generalized definitions include a phrase like "cluster of populations" (Mayr 1970, p. 12; Davis & Heywood 1963, p. 90; etc.). What is the relationship of the population to the species?

There are several levels of variation between population and species. Clausen & Hiesey (1958), in their classic study of ecological races in Dryocallis (Potentilla)¹ glandulosa, detected four such levels of variation: 1) between individuals of a population; 2) between isolated local populations in once climatic or edaphic region; 3) between populations growing in different climatic or edaphic regions; and 4) the taxonomic subspecies, morphologically

1. The first genus is that accepted herein; the genus in parenthesis is the one accepted in the cited work.

easily recognizable over a broad region and ecologically distinct. As they state and abundantly show, the overlapping interaction among these entities and the four levels they occupy provides a very complex structure. The variation at level (3) described above, if it defines clusters of populations based on different climatic or edaphic regions, may be said to describe ecotypes; if they are morphologically differentiable they may be described as subspecies. Clausen, Keck, & Heisey (1940) found ecotypes within Drymocallis (Potentilla) glandulosa, Potentilla gracilis complex (including P. diversifolia), and the P. drummondii-P. breweri complex (in sect. Multijugae), but they were morphologically distinguishable only in D. glandulosa, whereas the ecotypes were in general not morphologically distinguishable (and therefore, not meriting subspecies rank) in the other two complexes. These latter two complexes are, as we shall see, largely apomictic and high-polyploid.

3. The Nomenclatural Hierarchy

The structure of formal nomenclature, as distinct from the levels of variation described above, includes ranks below the species level:

species
subspecies
variety
subvariety
forma
subforma (Lanjouw et al. 1966; Davis & Heywood 1963).

The subspecies is usually thought of as "a regional, distinct facies of a species" (Davis & Heywood 1963, after Du Rietz), which concept is obviously dependent upon the prior delimitation of the species; that is, for a subspecies to be recognized, the particular species within which it occurs must be defined and delimited. Many plant taxonomists use the level of "subspecies" as the one level below that of species; a few use variety in addition to subspecies, and a few use the two terms alternatively. Often the variety is taken as a "local variant" (Davis & Heywood 1963), with a geographical extent much less than that of the subspecies.

Occasionally a plant taxonomist will use the category "forma" (e.g., Wolf 1908), usually in the sense of "a sporadic variant distinguished by a single or a few linked characters, without a distinct distribution" (Davis & Heywood 1963, p. 101). Camp and Gilly (1943) advocate the use of subspecies and forma as the only categories below that of species, with the definitions much as cited above; they seem to indicate that there may be cases where naming of taxa is not justified at either level.

It is not clear how these levels of the formal taxonomic hierarchy mesh with the "levels of variation" based on increasing larger clusters of populations described by Clausen & Heisey. The variety may possibly correspond with level 2 or 3 (as described above), however it is significant that Keck in Clausen, Keck, & Heisey (1940) only recognized the subspecies of Drymocallis glandulosa and did not attempt to formally recognize varieties. The forma is even less certain as a classification mechanism for populations, since it fails to account for the rather considerable variation expected within and among populations; only a forma showing intrapopulation uniformity with regard to some (morphological) feature of interest is consistent with the taxonomic system.

In some cases, for example in the classifications of cultivars within a cultigen, formal nomenclatural recognition of clusters of populations may not be justifiable or possible. In such cases, informal terms without official status may be more realistic, for example, "divisions" and "groups" of cultivars in Manihot esculenta (Rogers & Fleming 1973).

4. Studies of Populations using Morphological Characters

Many studies of populations, in an attempt to clarify the breeding relationships among individuals and thus speak to the concepts of population and of species based on barriers to crossing, have concentrated on methods designed to assess the genetic interactions among individuals. These methods have often used uniform-garden crossing experiments or, more recently, measures of genetic composition such as patterns of alleles as revealed by electrophoresis of enzymes; other studies have measured variation in chemical constitution, anatomical structure, or physiology. Relatively few systematic studies of populations have used morphological data, although most have interpreted their results in morphological terms.

Considering the variation within a population, the variance in a character among individuals of a population is often seen as the sum of a genetic component and an environmental component:

$$V_P = V_G + V_E,$$

where V_P is the variance in the phenotypic, measured character; the character under consideration here is usually thought of as a metrical, continuously-varying character, but integral or quantified characters could be used if they are well-ordered and have a relatively large number of states. The genetic and environmental components of variance could be estimated, for example, by comparison of two separate experiments each in a variety of environments, one experiment with a population that is known to be uniform genetically (such as the progeny of a cross between highly-inbred lines), and second experiment with a population composed of a variety of genotypes. However, in samples of native populations such comparisons are usually not possible; in these cases, a crude estimate of the components of variance may be made by separating the environmental component of variance into that due to within-individual differences and that due to between-individual differences:

$$V_P = V_G + V_{Es} + V_{Eg},$$

where V_{Es} stands for the environmental component of variance due to special, temporary, or localized circumstances, and V_{Eg} is the general environmental variance derived from permanent or non-localized circumstances (Falconer 1960, p. 143). The repeatability of the character can then be defined as

$$r = \frac{V_G + V_{Eg}}{V_P} = 1 - \frac{V_{Es}}{V_P}.$$

The repeatability is thus a measure of the relative contribution of the permanent, non-localized variation in a character to the total variation in the character; it is a combination of effects due to the genetic composition of the population and the general environmental effects. To understand the value of r , consider that the genetic component of variance is often separated further:

$$V_P = V_A + V_D + V_I + V_E = V_G + V_{Es} + V_{Eg}$$

where V_A is the genetic variance due to additive effects, V_D is that due to dominance, and V_I is that due to interaction between them. In many cases, the additive component is the largest one, and often it is the only genetic component measured; also, in several cases, the general environmental variance is small. Therefore,

$$V_P \geq V_A + V_{Es}, \text{ and}$$

$$\frac{V_A}{V_P} \leq 1 - \frac{V_{Es}}{V_P} = r.$$

In this way, the repeatability is a measure of the upper bound on V_A/V_P , which is called the heritability of a character, commonly used to measure the degree of correspondence between the state of a character (in statistical terminology, the "value" of a character) in an individual and the average state of that character in its offspring.

In studies of variation among plant populations, Allard (1970) surveyed the history of methods of sampling populations to date, and reported that there seems to be two kinds of pattern in character variation among populations:

1) clinal, in which a morphological character increases (or decreases) continuously with some ecological or geographical variable, such as altitude, moisture, mean temperature, and soil depth; and 2) patchwork or mosaic, in which sharp differences can be detected among local populations, without any apparent functional relationship to any ecological or geographical variable. Clinal variation has been found in many species of a wide variety of breeding modes, in fact Allard states that similar clines have been found "in all species for which adequate measurement data are available" (1960, p. 99). In contrast, most of the instances of patchwork or mosaic variation that he cites are in grasses with predominantly self-pollinated breeding (e.g., Marshall & Allard 1970, Allard & Kannenberg 1968); recent examples can be found among outcrossing plants, for example in the perennial prairie herb Liatris cylindracea (Schaal 1975, Schaal & Levin 1976). Kannenberg & Allard (1967) found that some morphological characters are more variable locally in outcrossing species, and some are more variable in inbred species. Intra- and inter-population variation is apparently not a function of breeding structure or mode taken by itself, as once thought (Stebbins 1957), but other factors must be taken into account.

Many studies on plant populations have focused on the role of hybridization in evolution, which studies have provided an opportunity to examine variation within and among populations. Notable in this discussion is the work of Anderson (1949, 1953), who advocated studying populations directly in their natural state, "so that the effects of the evolutionary forces at work could be measured in natural populations" (Anderson 1953, p. 280). His vehicle for demonstrating the effects of evolution in populations was the investigation of "introgressive hybridization," in which two related biotypes hybridizing in a zone of contact show directional variation in a number of characters from one biotype towards the other. Anderson (1948, 1949) showed that introgression would proceed most effectively where a range of habitats

intermediate between the two "parental" habitats occurred in the zone of overlap, and that this introgression proceeded from hybrid individuals back-crossing to one of the parental biotypes. Introgression may be a method by which hybrids are stabilized (Stebbins 1959); in recent years, as the number of documented cases of hybridization has increased, its role in speciation has become more important (Stebbins 1970).

Anderson (1949, 1957) also pioneered the use of the "scatter-diagram" composed of "metroglyphs" for pictorial representation of hybridization, in which six or more characters can be visualized on one two-dimensional graph. This method of pictorial representation has been used by many workers since Anderson made it popular; one of them is the study of hybridizations in the apomictic complex around Bothriochloa intermedia in southeast Asia and Australasia (Harlan & de Wet 1963), in which the authors propose the term "compilospecies" for a species which absorbs other germplasm by hybridizing widely with various related species. They hypothesize that this species contains genetic material from at least five other species.

A unidimensional measure of hybridization, that has been widely used, is the "hybrid index" (Anderson 1949, p. 88 ff.), a simple discriminant function that for a number of characters assigns the state 0 to those individuals expressing the character as in species A, and state 2 as in species B; those individuals intermediate are assigned state 1. The hybrid index value for each individual is then the sum of the states for all the characters. For example, Grant (reported in Mettler & Gregg 1969, pp. 202-204) showed that two species of Aquilegia which normally have distinct ranges and morphology in northern California do hybridize in one locality, and there show the characteristic flat frequency diagram of hybrid index, whereas the two "pure" populations have narrow peaks on opposite ends of the frequency distribution. Grant originally ascribed the distinctness of these two species to pollinator prefer-

ence of these two strikingly different flowers, but more recently Chase & Raven (1975) have taken data from more populations, including the one from which Grant sampled, and while confirming the hybridization, found a variety of pollinators on flowers of both species and their hybrid. They credit the distinctness of the species to ecological differences between the habitats of the two species; however, the controversy continues.

Anderson (1941, 1943) advocated the use of "mass collections", to adequately measure the variation within and between local populations; these are large collections of whole plants or parts of plants from one locality. Woodson (1947, 1953) used this technique with some modifications in his amazing study of leaf variation in Asclepias tuberosa. He measured leaf apex and basal angles, leaf width and leaf length on many herbarium specimens and population samples of this species throughout its range in eastern, central, and southwestern U. S., in which he found clinal variation in the two leaf angles, and evidence of introgression at many localities.

The relationships among hybrid populations has been shown using scatter-diagrams by, for example, Levin (1967) in annual Phlox species, in which the intermediate nature of the hybrids was confirmed using chromatographic data; and by Wilcock in perennial species of Stachys (Wilcock 1974). Emerson (1943, 1945) made a very complete study of the populations of a species of Clematis on the Ozark Plateau; using statistical analysis of morphological data from many populations, he showed that variation occurs in at least four nested levels of geographical clusters. In each of these levels, there are different suites of characters that serve to differentiate the units (clusters of populations). This species is probably largely sexual, outcrossing, and variation apparently occurs all at the diploid level.

In contrast, in the genus Antennaria species are highly variable in chromosome number, dioecious, and apomictic; in some species staminate plants have never been observed. Beals (1968) arranged pistillate plants in an

ordination; he found that the first axis of the ordination was related to hybridity, and the second to polyploidy, although the data and reasoning for these conclusions are only partially given. In general, although some species often dominated sectors of the ordination, others were scattered; the staminate plants (worked separately) were found to be clustered more distinctly by the ordination method used. In pistillate plants, there was a large degree of continuity in all characters measured, as well as evident continuity along the axes of ordination.

Some studies have shown difficulties in defining subspecific entities. Kruckeberg (1951) found that species growing on serpentine soils in California formed local populations on outcrops that were highly differentiated from one another, yet he could find no units between the populations and species. Bradshaw (1959) showed that the perennial grass Agrostis tenuis formed well-defined local populations with regard to the plants' physiological tolerance to various contaminants in the soil; yet these populations were not morphologically differentiated. Bradshaw concludes that subspecific classification is not warranted; yet he has overlooked a later paper by Kruckeberg (1957), in which he demonstrates that the annual Crucifer Streptanthus glandulosus forms well-marked geographic races based on morphological characters. Hybrids between geographical races, which Kruckeberg identifies as subspecies, show markedly reduced pollen fertility. Hickman & Johnson (1969), in a geographical analysis of morphological characters in the shrub Menziesia ferruginea in the Pacific Northwest, revealed that "no single character or set of characters studied can be used to separate individuals into geographically or ecologically coherent categories. Thus, the erection of subspecific taxa is inappropriate."

All of the population studies surveyed have shown a large degree of morphological variation among individuals within a population. When the variation among populations is considered, it may be seen that some of the

variation may be clinal for each character; a cline may have a geographical axis closely approximating the axis for other characters, as in Asclepias tuberosa, or the variation may be a more complex multivariate network, as in Menziesia ferruginea. The examples of clinal variation are mostly from out-crossing, sexual, perennial species. Variation among populations may also be in a patchwork or mosaic pattern, usually accompanied by smaller populations, with a large number of these "micro-populations" in a local area; this pattern is often seen among predominantly self-pollinating species, such as Festuca microstachys, or species where there are fairly strong local forces restricting dispersal or pollination, as Liatris cylindracea. A more complex situation is seen in apomicts (Antennaria), where local populations may not be formed; all characters vary continuously in complex, multifactorial fashion, with no apparent relation to locality or geographical region.

From the studies surveyed, no trend seems evident in whether, based on morphological data, subspecific clusters of populations can be recognized; in some studies such clusters are obvious, in others they can be shown after some difficulty, and in still others no such cluster can be shown.

Population Studies on Species in the Tribe Potentillinae

The landmark study by Clausen & Hiesey (1958) on Drymocallis (Potentilla) glandulosa has already been cited. As an introduction to a complex study of genetic structure of races within this species, they surveyed the morphological variation; the subspecies that they recognized are easily distinguished one from another on gross morphological characters such as petal length relative to sepals, inflorescence branching pattern, height of stems, and petal color. These morphological characters are well-correlated with geographical regions (Clausen, Keck, & Hiesey 1940, pp. 33-35). In this outcrossing, sexual diploid (uniformly $2n = 14$) species, they found that each subspecies had a wide variation within it; this variation may be clinal, as the variation in plant height with altitude. However, a considerable proportion of the variation is within populations, as shown in leaf length, leaflet number, plant height, leaf width. Mean height of stems shows random variation from population to population, when the mean values of each population are considered, within several subspecies. Characters showing clinal variation in one subspecies may show random variation among populations in another subspecies.

One of the most studied species in this tribe is Argentina (Potentilla) anserina, a perennial herb with vigorous vegetative reproduction by stolons, widespread in wet meadows in much of the north temperate zone. Ockendon & Walters (1970) reported that plants with more vigorous vegetative spread produced fewer flowers; careful study of breeding mechanisms has not been done, although some suggestion of self-incompatibility is noted. Tetraploid ($2n = 28$) and hexaploid ($2n = 42$) populations are known, but the hexaploid are much less common. Rousi (1965) found three hexaploid populations among 51 that he sampled in North America and Scandinavia; Ockendon & Walters (1970) found four hexaploid populations in 33 they sampled in the British Isles. In an extensive study of variation within and among populations of this species, Rousi (1965) calculated means and standard errors for nine leaf characters

and nine floral characters; most of these characters were quantitative measurements or ratios. He calculated correlation coefficients for pairs of characters from a reduced set of 13 characters, for 19 populations grown from seed in an uniform garden; seven of the characters for this study were highly correlated with other characters, and there seemed to be a considerable systematic difference among populations with respect to their correlation patterns. He reported no morphological differences between the hexaploid and tetraploid populations. Rousi also studied hybridization in several natural populations in Sweden and Finland, illustrating hybrid relationships by means of scatter diagrams and frequency distributions of hybrid index.

Ockendon & Walters (1970) sampled three morphological characters in tetraploid and hexaploid populations of A. anserina in the British Isles; although they only studied 33 populations, they found considerable variation within populations for each of the three characters, with no clear geographical discontinuities evident. The distribution of the hexaploids does not seem to follow any pattern, which supports Rousi's suggestion that they arise occasionally from time to time and at widely separated localities within the range of the tetraploids; the hexaploids reproduce almost entirely vegetatively. Close morphological similarity between hexaploid and tetraploid populations was also demonstrated in Cobon & Matfield's (1976) study of a single hexaploid clone of this species.

Hancock & Bringham (1978) sampled 13 populations of the diploid, sexual, hermaphroditic species Fragaria vesca in California; they found highly significant interpopulation variation in 25 morphological characters. Many of these characters were highly correlated with environmental variables such as rainfall, seasonal temperatures, soil-particle size, and soil salinity; the correlations were usually found significant in blocks, so that no one character could be "explained" by only one or a few environmental variables. Thus the relationship among these populations is very complex-clinal.

In the genus Potentilla in the strict sense, there are few studies of morphological variation within or among populations. Borhidi & Isepy (1966) made biometrical studies on herbarium specimens of three apomictic Potentilla species of eastern Europe; using discriminant analysis very similar to Anderson's (1949) use of scatter diagrams and hybrid indices, they demonstrate that one of these species is probably a hybrid between the other two.

Dansereau & Steiner (1956) studied five species of Potentilla in central Baffin Island; three of these species were sampled from one locality, and five morphological characters were measured on 45 plants. Many of the possible combinations of states of the five characters were found within the population; the variation pattern seems to be very complex. These three species are probably highly apomictic, to judge by the relatively high and odd-euploid chromosome numbers recorded by these authors.

Apomixis and Polyploidy in the Genus *Potentilla*

The following discussion is intended as a literature review, with the objective of forming a tentative hypothetical population-structure for the plants to be studied. Except for samples of somatic chromosome numbers from populations, this thesis study cannot conduct the embryological or crossing experiments necessary to ascertain the breeding structure of these plants.

Gustafsson (1946-7) summarizes the situation in the genus *Potentilla*, which is considered very difficult taxonomically: there are a large number of local biotypes in the old and new worlds, many of which have received names. The European forms have received the most attention, in which apospory with parthenogenesis and pseudogamy is most common, but some forms have also been shown to produce seed by diplospory with parthenogenesis and pseudogamy (Rutishauser 1948, terminology in Nygren 1967); the apomixis is often facultative. There are a very few forms that are diploid and apomictic ($x = 7$ throughout the genus); most forms that have been studied have the diploids obligately sexual and the polyploids with increasing degrees of apomixis. Gustafsson (1946-7) identified 27 apomictic species-complexes in *Potentilla*, many with high polyploidy, in each of which is found intricately complex polymorphism. There is evidence that the apomictic biotypes are at least as heterozygous as the sexual ones, perhaps more so; species-crosses are common wherever two or more species come into contact (species-hybrids). By the combined processes of hybridization and dispersal, "many apomictic micro-species are continually being split up into populations having wide ecological range."

The chromosome numbers that have been recorded in the genus in the broad sense are shown in Table 1; the numbers across the top of the Table represent the groups in the monograph of the genus by Wolf (1908). Table 2 lists the names of the groups, and in some cases, the genera to which these groups are now referred; the groups as used by Wolf are probably analogous to sections.

The chromosome numbers in Table 1 have been compiled from Dansereau (1955), Gustafsson (1946-7), and a variety of other sources.

In several of the genera that Rydberg and others (e.g., Dansereau 1955) have segregated from Potentilla, generative apospory is unknown. All investigations of breeding structure in Pentaphylloides, Comarum, Drymocallis, and Argentina have shown them to be sexual, outcrossing, and self-incompatible; Pentaphylloides and Drymocallis are largely diploid (Løve 1954; Clausen, Keck, & Hiesey 1940; Clausen & Hiesey 1958), whereas Comarum and Argentina are predominantly tetraploid with rare, sporadic populations at higher ploidy levels. The closely related genus Fragaria (probably closer to Potentilla s.s. than Pentaphylloides, Drymocallis, or Argentina are) is entirely sexual, outcrossing, and self-incompatible, with different widespread species at diploid, tetraploid, hexaploid, and octoploid levels (Staudt 1968). In Fragaria, there is a clear correlation between ploidy and degree of dioecy, the octoploids being completely dioecious; there is some evidence that the higher polyploidy in this genus has been produced by pre-meiotic reduplication of the chromosomes, which accords with the studies showing genetic segregation of several loci in the manner of autopolyploids (Staudt 1968, Asker 1971). In this regard, it is significant that all the intergeneric hybrids successful between Fragaria and Potentilla have been with species of Pentaphylloides and Drymocallis: the crosses attempted between Fragaria and Potentilla s.s. have all failed (Ellis 1962, Asker 1969). The breeding system of Potentilla s.s. seems strikingly different from that of related genera.

The chromosome numbers in Potentilla are mostly euploid, that is, at integral multiples of the basic number, $x = 7$. There is a small aneuploid series in the group Tormentillae, and long series with very high numbers in the groups Graciles and Multijugae; in these groups there have been no diploids or tetraploids reported. The chromosome numbers reported in Multijugae to date have been:

<u>Species</u>	<u>2n</u>	<u>Reference</u>
<u>P. breweri</u>	72-73, 99, 100, 102	Clausen et al. 1940
<u>P. drummondii</u>	64-108 105	Clausen et al. 1940 Shimotomai 1930
<u>P. diversifolia</u>	82-84, 91, 101 142	Clausen et al. 1940 Gustafsson 1946-7

From the high aneuploid numbers, one can infer some degree of apomixis, but as far as known, this mode of reproduction has not been shown for any member of this group.

From this discussion it can be seen that the species of sect. *Multijugae* may be facultatively apomictic, with a large proportion of the offspring of each individual being formed apomictically, and thus having a genotype close to that of the maternal genotype. The progeny will not be exactly maternal, because aberrations in meiosis cause segregation of a variable number of chromosomes, hence the offspring will have a range of chromosome numbers. This likely means that in a local area, phenotypes may be nearly alike, and in that local area the population may resemble a clone. The author's personal observations indicate that these clonal populations may differ greatly from one another, while still retaining a striking intrapopulation homogeneity for morphological characters.

Superimposed on this hypothetical picture of a large number of localized clones that may differ strikingly from one another, is the hybridization between populations that probably happens whenever two populations of closely related species (even in different sections of the genus) come into contact. Pseudogamy probably facilitates this hybridization, since it tends to increase the range of pollen-types that will grow in a given style, and hence more possible combinations of microspore and megaspore will be brought together closely in the ovary.

Taxonomic Review of *Potentilla* sect. *Multijugae*

The following discussion is made in order to determine the proper circumscription of sect. *Multijugae*, and the entities within it, using traditional taxonomic methods and the field experience of the author. This is done so that the population studies and classification of species to follow will be done within a natural group, as far as possible.

Potentilla sect. *Multijugae* Rydberg was established in 1898 to include

P. millefolia
P. arizonica
P. pinnatisecta (*P. ovina*)
P. plattensis
P. richardii
P. cascadiensis
P. drummondii
 and *P. multijuga*.

Wolf (1908) retained most of the species in Rydberg's *Multijugae*, removing only *P. richardii* to his sect. *Rivales*; he added to *Multijugae* the species:

P. saxosa (*Horkelia saxosa* of Rydberg 1898)
P. rosulata (described by Rydberg in 1899)
P. candicans (sect. *Candicantes* Rydberg 1898)
P. dissecta
P. diversifolia

The last two species had been combined under the name *P. dissecta* by Rydberg in his sect. *Aureae*, along with several other taxa:

P. dissecta var. *glaucophylla*
P. decurrens
P. ranunculus
P. sierra-blancae

The last two species were part of Wolf's sect. *Ranunculoides*. Both Wolf (1908) and Rydberg (1898) had separated all of the above from *P. breweri* and its var. *expansa*, *P. crinita*, and *P. lemmonii*, Rydberg as part of his sect. *Leucophyllae* and Wolf as part of his sect. *Graciles*.

Rydberg in 1908, working independently of Wolf (but published later), described seven new species in the group of taxa under discussion; he made many changes which are difficult to understand in a simple way (diagrammed in Fig. 1). Perhaps the most notable of these changes are three: 1) the establishment of

a new sect. *Saxosae* for *P. saxosa*, *P. rosulata*, and *P. acuminata*; 2) the inclusion of *P. decurrens*, *P. crinita*, and *P. lemmonii* in sect. *Multijugae*; and 3) description of *P. bruceae*, allied with *P. breweri* in his sect. *Leucophyllae* but clearly related to *P. drummondii* in sect. *Multijugae*.

There are some preliminary conclusions that can be made about the circumscription of sect. *Multijugae*, without discussion of the problem of synonymy of species:

1. *P. richardii*, as becomes apparent when most material is seen, is a central Mexican species of close affinities with *P. brevifolia*, of high mountains in eastern Oregon, Idaho, and northwestern Wyoming, probably also in Montana. These species are part of a small section of trifoliolate plants with prostrate stems and no tomentum, which includes *P. flabellifolia* and *P. grayi*. There has been some confusion because *P. brevifolia* and *P. richardii*, while being truly trifoliolate, nevertheless have their terminal leaflet deeply pinnately lobed, thus the leaf appears to be pinnate. These species seem to form a natural group and should be excluded from sect. *Multijugae*.

2. Sect. *Multijugae* as circumscribed by Rydberg (1908) seems to be a natural group of species; however, there are apparently close ties with three other groups of species to merit their inclusion:

3. *P. candicans* is obviously closely related to *P. plattensis* (especially its prostrate form) and *P. millefolia*; it differs only in its distinctive pubescence color, silvery-yellowish. It should be included in the section.

4. The cluster of forms around *P. diversifolia* is related in several ways. Subdigitate forms of *P. diversifolia* with narrow leaflets closely approach *P. pinnatisecta*; in fact, *pinnatisecta* was originally described as a variety of *P. diversifolia*. Nuttall made notes on the holotype and one of the isotypes of *P. plattensis*, that it was related to *P. diversifolia*; *P. decurrens* seems intermediate between *P. pinnatisecta* and *P. diversifolia*. Large plants of *P. diversifolia* that occur sporadically through its range are remarkably

similar to P. drummondii in its glabrate phase. P. sierra-blancae is probably a good species, disjunct morphologically and geographically from the main range of P. diversifolia.

5. P. breweri differs from forms of P. drummondii only in its distinctive, silvery-gray pubescence; in fact, glabrescent forms of P. breweri are difficult to distinguish from small plants of P. drummondii (Clausen, Keck, and Heisey 1940). At the same time, P. breweri is related to P. ovina, differing in pubescence and form of the terminal leaflet.

6. P. saxosa, P. rosulata, and P. acuminata form a small group of species of the desert mountain ranges in southern California, Baja California, and western Arizona, which group is poorly known but probably related to the genus Purpusia. They stand out in habitat and morphology from sect. Multijugae, and deserve a section of their own.

7. P. crinita and P. lemmonii do not seem to be closely related to any species in sect. Multijugae; P. lemmonii is only one of several transitions in leaf-form and pubescence between P. crinita and a very diverse group called P. concinna for lack of a better name and adequate assessments of its internal variation. P. concinna is itself a problematic group, and relationships to it are difficult to assess at this time; but P. crinita and P. lemmonii should be excluded from sect. Multijugae.

8. P. jucunda probably represents a hybrid between P. diversifolia and P. gracilis var. glabrata (Lehm.) C. L. Hitchcock (1961), although this latter taxon is part of another very difficult group. Intersectional hybrids are fairly common in Potentilla wherever two populations share a habitat.

With these considerations made, the section can be described:

Potentilla L. sect. Multijugae Rydberg (1898, pp. 30-31). Perennial herbs from a shortly-branching woody root; stems ascending, erect, or often prostrate, usually less than 3 dm long; radical leaves digitate or subpinnate to more often conspicuously pinnate, with 2-15 pairs of leaflets which are each coarsely toothed; leaves glabrous to hirsute or strigose, rarely also with dense tomentum, never bicolored; inflorescence usually many-flowered with conspicuous pedicels that sometimes

recurve in fruit, not apparently leafy; receptacle short-hairy; petals 5-10 mm long, yellow, obcordate-emarginate; stamens 25-30; achenes glabrous, shining, 1.0-1.8 mm long; styles terminal, thickened just above the base, slender, long-protruded and filiform, 2-3 times as long as the mature achene.

Thus defined, sect. *Multijugae* includes the following, all described as species by Rydberg in 1908:

Map No.	Species
1	<i>P. arizonica</i>
9	<i>P. breweri</i>
5	<i>P. bruceae</i>
10	<i>P. candicans</i>
9	<i>P. cascadiensis</i>
8	<i>P. decurrens</i>
D	<i>P. diversifolia</i> (<i>P. dissecta</i>)
5	<i>P. drummondii</i>
D	<i>P. glaucophylla</i>
3	<i>P. hickmanii</i>
2	<i>P. klamathensis</i>
2	<i>P. millefolia</i>
7	<i>P. monidensis</i>
4	<i>P. multijuga</i>
6	<i>P. multisecta</i>
8	<i>P. nelsoniana</i>
7	<i>P. ovina</i>
D	<i>P. perdissecta</i>
8	<i>P. pinnatisecta</i>
1	<i>P. plattensis</i>
D	<i>P. sierra-blancae</i>
9	<i>P. versicolor</i>
D	<i>P. vreelandii</i>
7	<i>P. wyomingensis</i>

Synonymy of these taxa needs to be decided; in addition, since Rydberg's treatment several taxa have been described:

5	<i>P. anomalifolia</i> Peck
9	<i>P. breweri</i> var. <i>viridis</i> Jepson
2	<i>P. millefolia</i> var. <i>algida</i> Jepson
2	<i>P. millefolia</i> var. <i>densa</i> Jepson

which should be considered part of this section.

Sect. *Multijugae*, as described above, comprises plants which inhabit high mountain ridges and grassland, in the mountains from southern British Columbia and Alberta, down the Cascades to southern California and down the Rocky Mountains to central New Mexico and northern Arizona and on the Basin Ranges of western Utah, Nevada, southeastern Oregon and southwestern Idaho, disjunct in

the mountains of central Mexico; and inhabiting relatively lower wetland meadows along the western edge of the Great Plains from southern Saskatchewan and southwestern Manitoba to central New Mexico and east-central Arizona, and on the western slope of the coast Ranges of California and the intermontane valleys of northern California and southern Oregon. The distributions of the species of sect. *Multijugae* are shown in the maps, Figs. 2-5. The taxa have been grouped into species-complexes according to the map numbers shown in the text-table above; "D" refers to Fig. 2, the map of *P. diversifolia*.

Numerical Methods of Analyzing Taxonomic Structure

Multi-character methods are most useful in taxonomic studies, because at best, a small set of characters must be chosen which will effectively classify the organisms in the study, and traditional taxonomy lacks an objective way of doing this. At worst, which is probably the case in this study, the classification may have to be based on a number of characters considered simultaneously. It is difficult for a taxonomist to consider a number of characters simultaneously over a large set of objects.

The two leading methods of analyzing taxonomic structure based on data from many characters are ordination and clustering. Many methods for doing each of these two are described in Sneath & Sokal (1973). As they emphasize, most studies have focused on the species level or higher, and relatively few at the population level (1973, pp. 367-368).

At the species level or higher, there have been several studies contrasting different methods of classification. France, Rogers, and White (1969) compared two different principal-components analyses (methods of ordination) and two different clustering methods, compared and contrasted with the pre-existing taxonomic system, which had been arrived at using traditional taxonomic procedures. They found that the single-linkage clustering technique based on graph theory of Wirth, Estabrook, and Rogers (1966) gave the most useful results and allowed these results to be displayed in a way that more information about taxonomic structure could be visualized. Their study was designed to re-evaluate and complement the traditional taxonomic system, and to point the way for focus on problem areas, rather than to supplant the traditional taxonomy.

Bisby (1973) and Bisby & Polhill (1973) compared the traditional classification of the genus Crotalaria with three numerical procedures: single-linkage clustering, principal-coordinates analysis, and median clustering

(a method by which clusters are connected by their medians). They found, as before, that the single-linkage method with subgraph representation, was the best of the three methods for illustrating the patterns of similarities within the groups formed, and an indication of marginal and isolated species; these advantages provided some indications of where improvements might be made in the existing classification.

Selection of characters to be used in classifications is very important. Bisby & Nicholls (1977), in an important study of character selection and state structure within characters, compared six different classifications of species within the tribe Genisteae of family Leguminosae, using single-linkage clustering. They found a considerable difference in the classifications based on different character sets. However, Bisby (1973) found that selection of those characters that were most highly correlated with each other significantly improved the classification. The method he used for choosing those characters is the character-analysis program based on information theory developed by Estabrook (1967).

At the population level, Sneath & Sokal (1973) point out that few studies have used clustering techniques; most have used ordination. However, there is no reason to believe that the reservations expressed in the studies by Prance et al. (1969) or Bisby (1973) against the use of ordination for classification would not also apply at the population level. Rogers & Fleming (1973) used single-linkage clustering with subgraph representation to classify population samples within a cultigen, and produced a useful classification of cultivars.

At levels between the population and species, based on the comparative studies that have been made, single-linkage clustering with subgraph representation seems to be the best method for extracting information helpful in making a taxonomic classification. As Prance et al. (1969) state, this method makes it possible to follow the progress of the classification process and detail the procedure by which each item contributes to the clustering.

Materials and Methods

Population samples have been made from 49 different populations, listed in Table 2. These samples were made after first having made a preliminary, subjective assessment of the variation in each population; then a number of plants of each population were collected and pressed as herbarium specimens, in the manner of the "mass collection" technique of Anderson (1941). The sample size shown in Table 2 is the number of herbarium specimens that were sorted, which in many cases is about one-half the total number of individual plants in the sample, since several plants will eventually be mounted on each herbarium sheet. For each population sample made, a sample of at least five root-tips was fixed by the Svalbf modification of Navashin's method, as described in Löve & Löve (1975). This method has been reported to be of value in studies on other Potentilla species (e.g., Asker 1970). For many of these population samples, about 50 mature achenes were collected from plants of the population; this was done for all of the samples taken later in the season.

In addition, herbarium specimens of all of the species and inter-specific taxa in Potentilla sect. Multijugae and related species, have been borrowed from the following herbaria: ALTA, ARIZ, ASC, BRY, CAN, CAS, COLO, DAO, GH, IDA, MAN, MNA, MONTU, NY, ORE, PH, POM/RSA, RM, UC, UNM, US, UTC, WIN, WS, and WTU (abbreviations in Holmgren & Keuken 1974).

Population statistics will be calculated from a suitable subset of the populations listed in Table 2, excluding those with small sample size, and estimates will be made of the components of variance in each of approximately 10 characters. These characters will be chosen because of their use in taxonomic studies of this section, and will be limited to metric characters. Correlation coefficients will be calculated for all characters in each population, and in the union of all samples within the section under study.

A selected set of herbarium specimens (including an "exemplar" from each

of the population samples) will then be chosen, to represent the variation among populations within sect. *Multijugae*. These will be subjected to a character analysis using the procedure of Estabrook (1967) and Bisby (1970), which is computer program CHARANAL (Legendre & Rogers 1972), developed in the Taximetrics Laboratory, Department of E. P. O. Biology, University of Colorado. The results of this character analysis on selected herbarium specimens will be compared with the results from partition of variance components and correlation obtained from the population samples, to refine the list of characters and their states.

This refined set of characters will then be used to cluster a selected set of herbarium specimens, by the single-linkage method of Wirth, Estabrook, and Rogers (1966) and Bisby (1973). This technique was also developed in the Taximetrics Laboratory, Department of E. P. O. Biology, University of Colorado.

Aided by the results of this clustering technique, a taxonomic revision of this section will be presented, with complete discussion of interspecific and intraspecific variation and its meaning.

A polyclave key to the species of Potentilla in North America will be produced, using the method of Johnston (in press).

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P.L.	2n	1										2										3											
		1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	
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3	21																																
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Table 1.

Recorded chromosome numbers in *Potentilla s.lat.* Numbers across are numbers of the Groups (Geges) in Wolf (1908), listed in following table. Numbers shown between Ploidy Levels (P.L.) means that aneuploid numbers have been recorded for those groups. Data from Bolkhovskikh (1969), and a variety of other sources.

Group ("Grax") (after Wolf 1908)		Genus Name (after Rydberg 1908)
Number	Name	
1	Fruticosae	<u>Pentaphylloides</u> (Rydberg calls it <u>Dasiphora</u>)
2	Bifurcae	
3	Xylorhizae	<u>Trichothalamus</u>
4	Biflorae	
5	Palustres	<u>Comarum</u>
6	Tridentatae	<u>Sibbaldiopsis</u>
7	Eriocarpae	
8	Speciosae	
9	Nitidae	
10	Curvisetae	
11	Crassinerviae	
12	Cauliscentes	
13	Fragariastra	
14	Rupestres	<u>Drymocallis</u>
15	Multifidae	
16	Graciles	
17	Haematochroae	
18	Niveae	
19	Argenteae*	
20	Tanacetifoliae	
21	Rectae	
22	Rivales	
23	Persicae	
24	Grandiflorae	
25	Chrysanthae	
26	Multijugae	
27	Ranunculoides	
28	Aureae	
29	Fragarioides	
30	Tormentillae	
31	Anserinae	<u>Argentina</u>

* including Collinae

Table 2. Explanation of the numbers across the top of
Table 1.

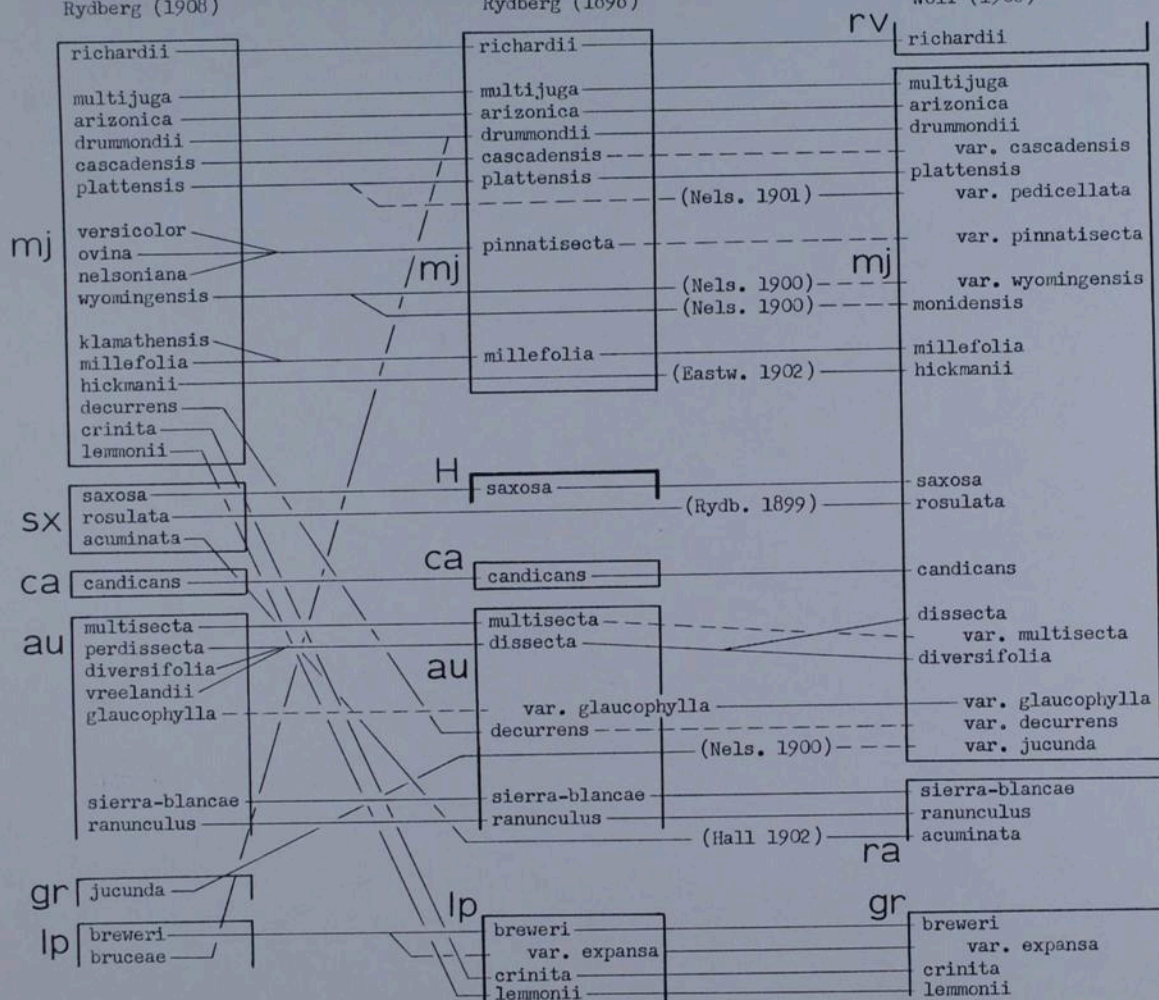
Fig. 1 . Showing the relationship among the three principal classifications of the genus Potentilla sect. Multijugae and its allies, compiled from information in Rydberg (1898, 1908) and Wolf (1908). For explanation see text. Abbreviations:

au	<u>Potentilla</u>	sect. Aureae Lehm.
ca		sect. Candicandentes Rydb.
gr		sect. Graciles Rydb.
H	<u>Horkelia</u>	
lp	<u>Potentilla</u>	sect. Leucophyllae Rydb.
mj		sect. Multijugae Rydb.
ra		sect. Ranunculoides Th. Wolf
rv		sect. Rivaes Th. Wolf
sx		sect. Saxosae Rydb.

Rydberg (1908)

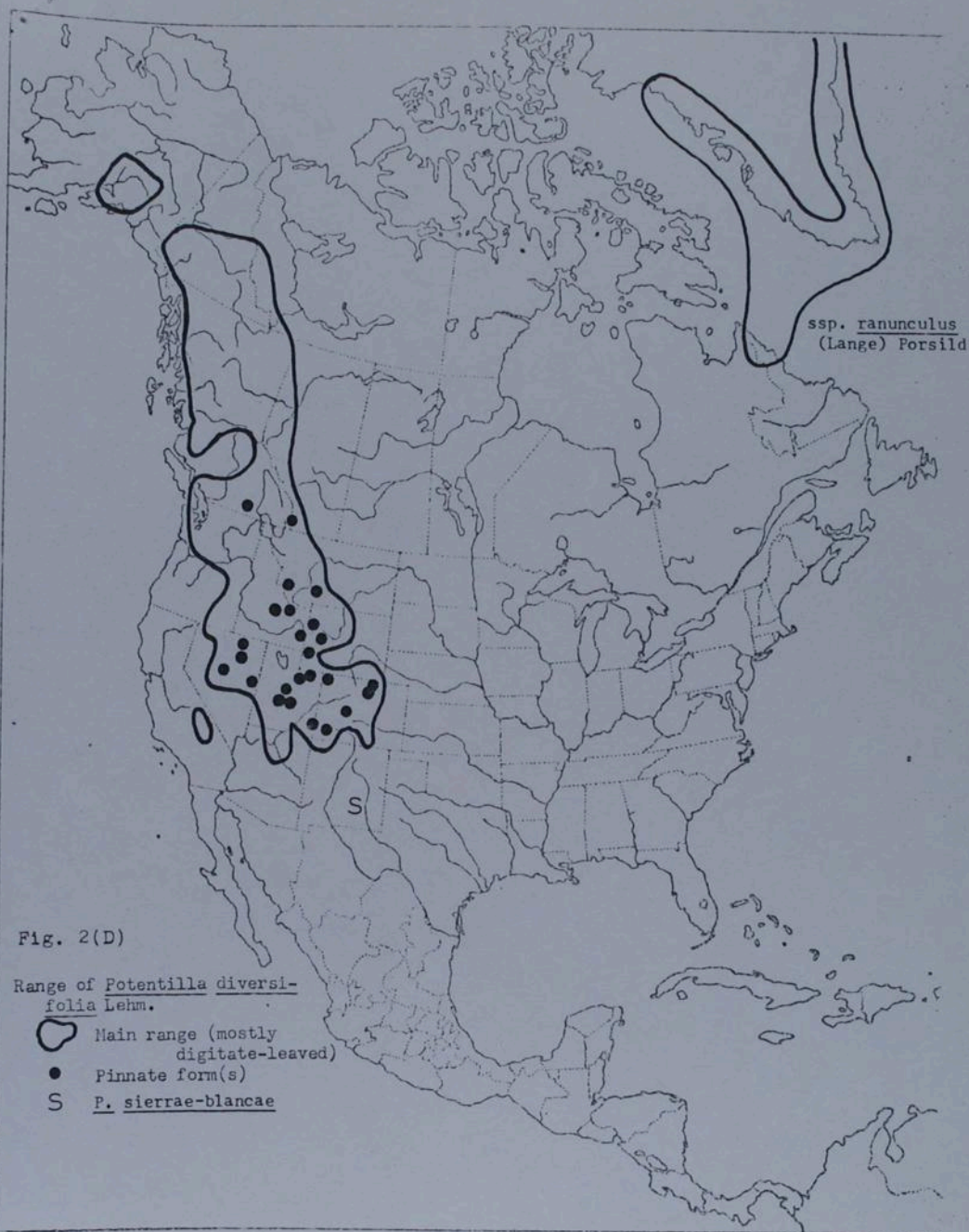
Rydberg (1898)

Wolf (1908)



	sample size	<u>Potentilla</u> species complex
1. Wyoming, Carbon Co., flat windswept limestone ridge ca. 25 mi SS of Rawlins, Continental Divide Ridge.....	16	?
2. Colorado, Moffat Co., top of Zenobia Peak.....	6	pinnatisecta
3. Colorado, Moffat Co., same locality.....	6	hybrid
4. Utah, Juab Co., head of Basin Creek, Deep Creek Range.....	27	multisetosa
5. Utah, Garfield Co., North Summit of Mt. Ellen, Henry Mts.....	20	concinna
6. Utah, Garfield Co., same locality.....	10	ovina
7. Utah, Garfield Co., Granite Ridges, Henry Mts.....	10	sp. nov.
8. Utah, Grand Co., ridge NW of Mt. Tomasaki, La Sal Mts.....	6	diversifolia
9. Utah, Grand Co., same locality.....	14	paucijuga
10. Utah, Grand Co., same locality.....	9	hybrid
11. Utah, Grand Co., same locality.....	14	nivea
12. Utah, Grand Co., same locality.....	11	ovina
13. Utah, Sevier Co., Pelican Point, Fish Lake.....	15	hippiana
14. Utah, Sevier Co., same locality.....	8	pennsylvanica
15. Utah, Wayne Co., top of Thousand Lake Mtn.....	20	diversifolia
16. Utah, Wayne Co., same locality.....	13	pulcherrima
17. Utah, Duchesne Co., top of ridge, upper Wedge Hollow.....	16	pinnatisecta
18. Utah, Duchesne Co., same locality.....	11	hybrid
19. Colorado, Gunnison Co., waterfall below Geneva Lake.....	5	diversifolia
20. Colorado, Gunnison Co., 1.5 mi SSW Pitkin.....	22	pulcherrima
21. Colorado, Gunnison Co., same locality.....	9	pennsylvanica
22. Colorado, Gunnison Co., west summit of Mt. Bellview.....	11	diversifolia
23. Colorado, Gunnison Co., same locality.....	20	pinnatisecta?
24. Colorado, Gunnison Co., same locality.....	8	nivea
25. Colorado, Gunnison Co., same locality.....	9	pulcherrima
26. Colorado, Clear Creek Co., near Loveland Pass.....	31	diversifolia
27. Colorado, Clear Creek Co., same locality.....	41	subjuga
28. Colorado, Park Co., $\frac{1}{4}$ mi NE of Jefferson.....	14	plattensis
29. Colorado, Park Co., same locality.....	4	pulcherrima
30. Colorado, Park Co., same locality.....	12	hybrid
31. Colorado, Gunnison Co., near Cottonwood Pass.....	18	diversifolia
32. Colorado, Gunnison Co., 0.8 mi WSW of Cumberland Pass.....	7	diversifolia
33. Colorado, Gunnison Co., same locality.....	28	pinnatisecta?
34. Colorado, Gunnison Co., same locality.....	16	subjuga
35. Utah, Duchesne Co., lower end of Long Park.....	11	pinnatisecta
36. Utah, Duchesne Co., same locality.....	6	pulcherrima
37. Utah, Uintah Co., Oaks Park.....	10	pulcherrima
38. Utah, Uintah Co., same locality.....	10	pinnatisecta
39. Utah, Summit Co., La Motte Peak.....	16	pinnatisecta-ovina
40. Nevada, Elko Co., above Island Lake, Ruby Mts.....	20	breweri
41. Nevada, Elko Co., same locality.....	12	breweri
42. Nevada, Elko Co., same locality.....	15	breweri
43. Nevada, Elko Co., same locality.....	9	diversifolia
44. Wyoming, Park Co., south end of Clay Butte.....	23	ovina
45. Wyoming, Park Co., same locality.....	9	pulcherrima
46. Wyoming, Albany Co., above Brooklyn Lake, Medicine Bow Mts.....	13	pinnatisecta
47. Wyoming, Albany Co., 2.5 mi SE of Centennial.....	6	plattensis
48. Colorado, Gunnison Co., above and E of Schofield Park.....	13	diversifolia
49. Colorado, Gunnison Co., same locality.....	4	pulcherrima

Table 2. Localities where collections of Potentilla populations were made during the summer of 1979.



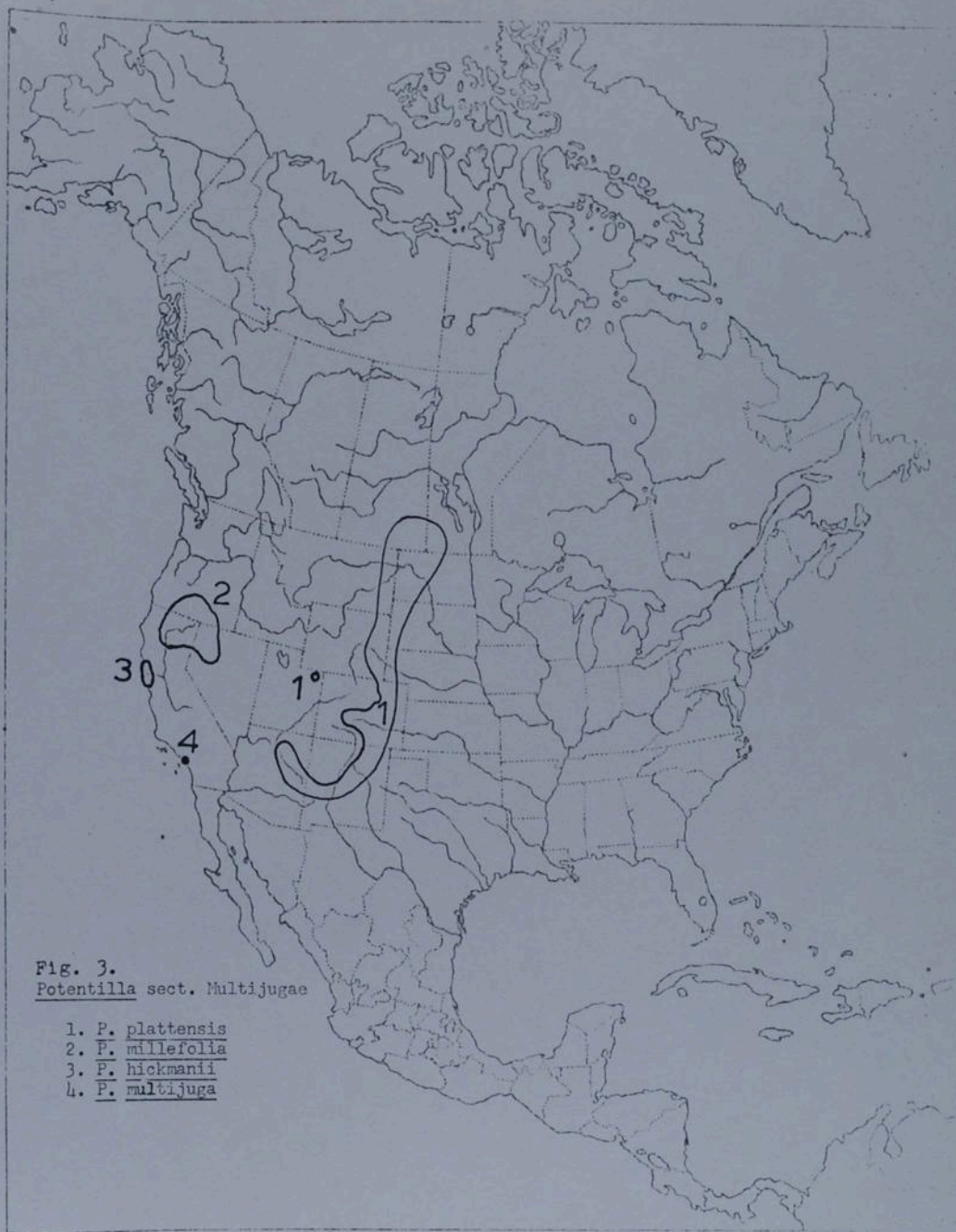


Fig. 3.
Potentilla sect. Multijugae

1. P. plattensis
2. P. millefolia
3. P. hickmanii
4. P. multijuga

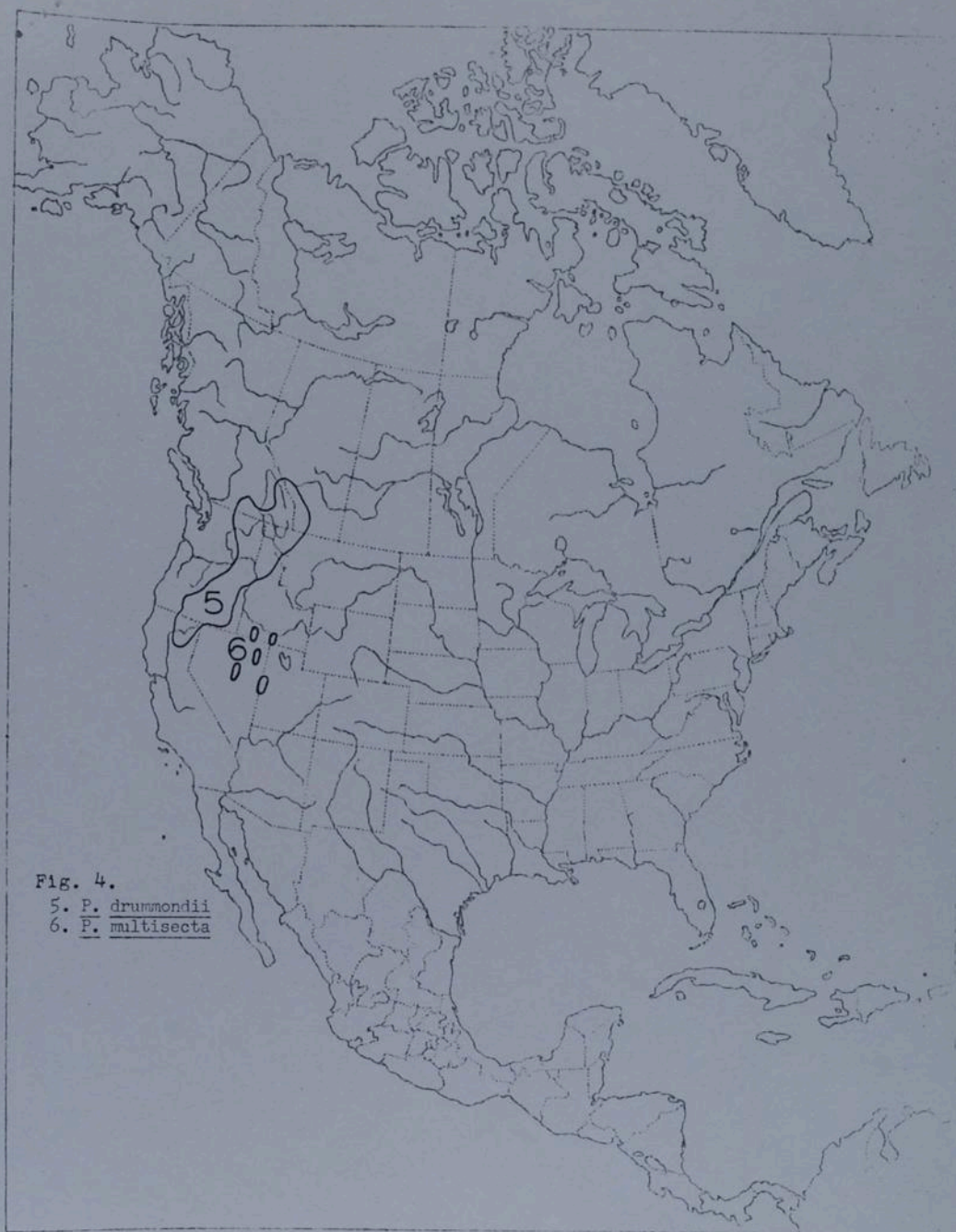


Fig. 4.

5. P. drummondii
6. P. multisecta

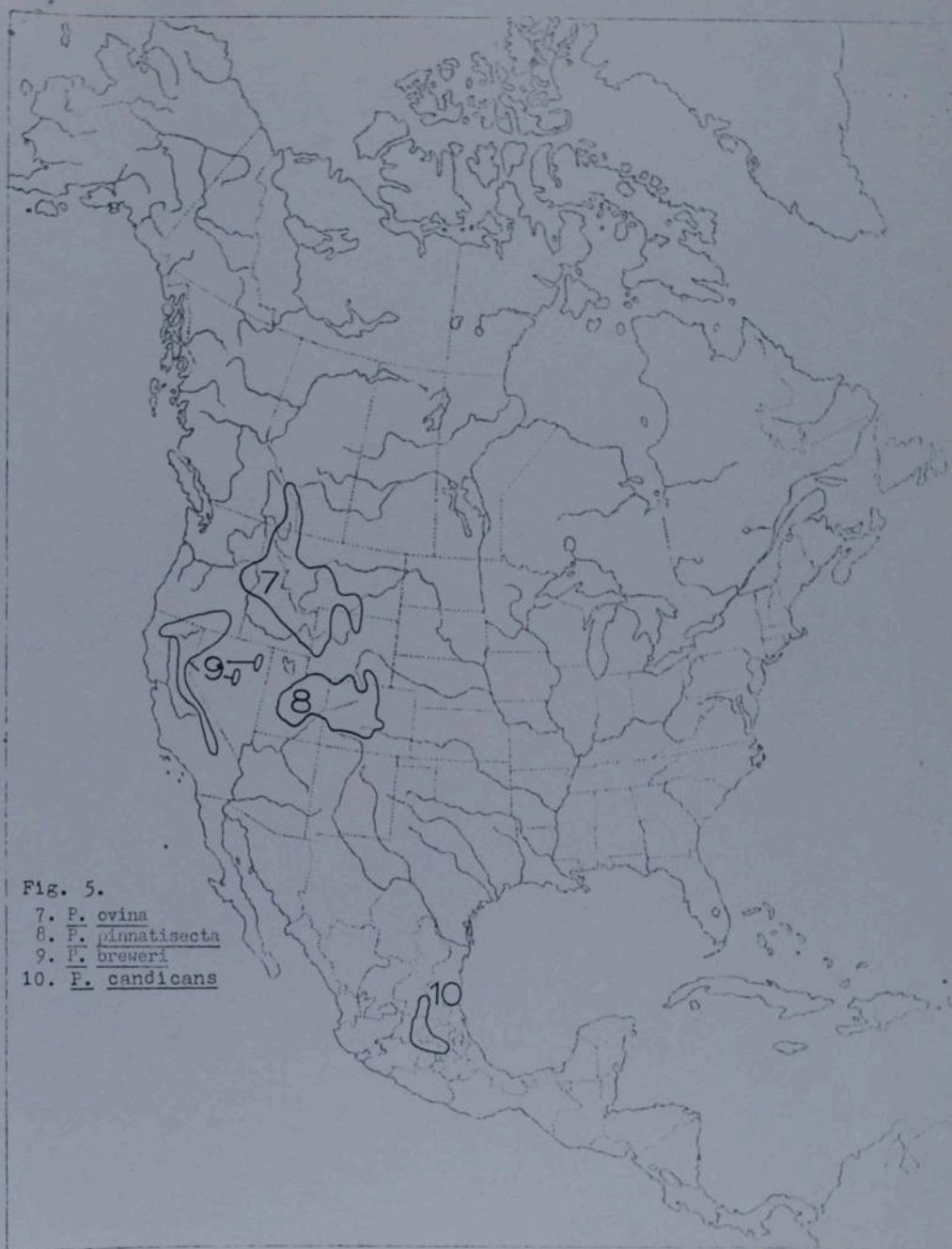


Fig. 5.

- 7. *F. ovina*
- 8. *F. pinnatisecta*
- 9. *F. breweri*
- 10. *F. candicans*

Questions for Barry Johnston's PhD prelim., April 2,3,4,5, 1979

Instructions:

1. You have been provided with questions in your four chosen areas by each member of your committee.
2. From these questions choose one or more and write for one half day in each category. Please identify the question.

General Biology

From Dr. Grant

1. Over the past few decades, several different schemes for classifying living organisms at the kingdom level have been proposed. Three, in particular, are most commonly used--one with a 2 kingdom split, one with a 3 kingdom split and one with a 5 kingdom split. Briefly discuss the criteria used for each of these three systems to assign organisms into their respective slots and provide your own critique of each.
2. Compare and contrast the structure of an animal cell with a plant cell (generalized in each case).

3. Describe the primary properties of two major classes of macromolecules which are crucial to all living organisms. (E.G. composition, function, etc.)

From Dr. Bye

4. Outline and describe the scientific method. How does this method apply to biological research concentrating on the diversity of organisms?
5. Compare mitosis and meiosis in plant and animal cells.

From Dr. Weber

6. Can you give an example of recent research on a fundamental life process, for example, cell division, mitosis, meiosis, which has a direct bearing on the classification of higher organisms. Develop.

From Dr. Rogers

7. Describe some of the various types of pollinating mechanisms in flowering plants and discuss how these affect speciation.

Ecology

From Dr. Marr

1. Describe the special features of the Hoosier Pass Area which make it a significant phytogeographical locality.
2. Describe the ways in which the Front Range resembles a range on another continent. How do they differ?
3. Define or describe and comment on the ecological significance of any six of the following:
(1) relative humidity, (2) evapotranspiration, (3) habitat, (4) azonal soil, (5) Merriam's Life Zones, (6) succession, (7) solifluction, (8) permafrost, (9) ecotypes.
4. Discuss the continuum concept versus the individualistic concept of plant community analysis.

From Dr. Bye

5. Select a plant species as an example to be discussed in parts (a) and (b):
(A) Describe an autecological approach to research on a given plant species.
(b) Describe a synecological approach to research on a given plant species.
6. Island biogeography is a recent popular field as a result, in part, of MacArthur's (and students') publications. Discuss the theory of island biogeography as it applied to terrestrial habitats. Give examples of important studies and suggest areas of future studies.
7. Define and discuss the pyramids of biomass, energy and numbers (density) as applied to theoretical ecology and to "practical" ecology.

From Dr. Weber

8. *Hymenoxys acaulis* has discrete races in Colorado which are alpine and steppe-desert, respectively, without colonized habitats in between. Can you construct a scenario suggesting how this particular bit of evolution and geographical distribution might have come about? Give your imagination free reign.

From Dr. Rogers

9. How do ecological and taxonomic classifications differ? Describe some of the computerized methods of ecological and taxonomic classification procedures to illustrate your answer.

From Dr. Grant

10. Define and discuss or identify the terms: community, biome, biosphere, competition, allelopathy, succession, community vs. continuum, Leslie matrix, G.E. Hutchinson, ordination, ecotype.

Continued on next page.

Dr. Grant's ecology questions continued.

11. Discuss some current views concerning the nature and causes of species diversity. E.g., latitudinal clines, maturity, resource level, etc.
12. Choose 5 major principles of ecology and illustrate the operation of each.
13. Trace the development of the current use of the term 'niche'.

Taxonomy and systematics

From Dr. Weber

1. Discuss the International Rules of Nomenclature as to innovations or changes that have been made in the recent Congress which tend to improve or retrogress the applications of rules to botanical taxonomy.

From Dr Grant

2. Outline the purpose and function of the science of taxonomy as you see it. Are there differing schools of thought? If so present and critique opposing views.
3. Discuss the definition, utility and weakness of the terms primitive and advanced in the context of phylogeny.
4. Discuss the biological species concept and its utility with respect to plant taxonomy.

From Dr Rogers

5. Describe and categorize some of the types of clustering analyses useful in taxonomic work.
6. Provide a detailed flow chart of data processing for a taxonomic problem.
7. Are there any real differences in taxonomic output today from those 150 years ago? Defend your answer.

From Dr. Bye

8. Discuss the various types of reproductive isolation mechanisms and their importance to speciation. Be sure to illustrate your comments with examples.
9. Taxonomy/systematics is expanding rapidly--often elaborating upon basic, age-old themes of earlier scholars. Discuss the "fronts" of development of taxonomy with respect to: (1) the basic concepts; (2) the new insight recent techniques and methods brought to bear on these major areas of investigations, and (3) the limitations we are still faced with today. Do you see systematics collections playing a more important role in the future or not? Justify your comment.

Genetics and Evolution

From Dr. Bye

1. How does hybridization play a role in evolution? Discuss various examples (from plant or animal cases) to illustrate your point.

From Dr. Grant

2. Trace the development of the current synthetic (Neo-Darwinian) view of evolution paying particular attention to the changes it underwent. Be sure to include a clear, concise statement of the way evolution is now thought to operate.
3. Describe the relative importance of polyploidy as an evolutionary phenomenon in plants versus animals. Include a discussion of why it is more common in one group than in the other.
4. A geneticist sampled 100 plants and looked at seed color in these plants. There were only two colors, green and yellow. He found that when he selfed some of the green plants, only green seeded progeny were produced no matter how many generations of selfing took place. Similarly, he found that selfed yellow seeded plants also produced only yellow seeded plants. Other green seeded plants, however, produced both green and yellow seeded progeny when selfed. Assuming simple Mendelian control of seed color, what proportion of the progeny array having both green and yellow seeds would be green? What proportion of these green would give rise to green progeny only? Which color is dominant? Diagram crosses which would show which color was dominant.
5. Trace the development of current ideas on the molecular basis for hereditary traits.

From Dr. Weber

6. Stebbins once described evolution as being a matter of reduction, fusion, and changes of symmetry, as it applied to flowering plants. Give detailed discussion of how this applies in a group which you are acquainted with, and indicate whether you agree with Stebbins or would choose to alter his statement.

From Dr. Rogers

7. Within the past decade or so there has been an increase in the number of papers dealing with cladistics. What is cladistics, and what are the directions being taken with respect to this field.
8. Define the term saltation as applied to evolution, give an example, and provide an hypothesis as to the genetic mechanisms involved.

Barry C. Johnston
17 April 1979

Systematics and Methods of Study in Potentilla

I. Systematic survey

- A. Rosaceae - Ascherson & Graebner (1904-1905); Challice (1974);
Sax (1931, 1933), Rydberg (1908), Yuzepchuk (1941)
- B. Potentilleae - Rydberg (1898, 1908); Yuzepchuk (1941)
- C. *Potentilla* s.str. - Rydberg, Yuzepchuk, Wolf (1908), Watson (1878),
Bate-Smith (1962), Keck (1938), Lehmann (1820, 1856),
Nestler (1816)

II. Methods of study

- A. Morphological, herbarium: Wolf (1908) and preceding; Hitchcock (1961)
- B. Statistical: Borhidi & Isepy (1966)
- C. Cytology & Embryology: Rutishauser (all refs.) Muntzing (all);
Asker (1970ab, 1971), Christoff & Papasova; Acharya-
Goswami & Matfield; Dansereau; Ellis; Clausen Keck &
Hiesey; Matfield & Ellis; Popoff; Sorokina
- D. Ontogenetic & Developmental studies: Troll (1935), Zhitkov (1972);
Kania (1973)
- E. Chemistry & Chromatography: Bate-Smith; Challice; Kohli & Packer;
Asker & Fröst, leading to
- F. Numerical methods: Asker & Fröst, my example.

III. Problems in systematics of the genus

- A. Why traditional taxonomy alone is insufficient
- B. Populations, biotypes, and variation
- C. Proposal: population studies

Literature

- Acharya-Goswami, D. & Matfield, B. (1974). Pseudogamy in the genus Potentilla L. New Phytol. 73:1243-1247.
- P. argentea, P. recta, and P. hirta produced progeny when pollinated interspecifically or against each other, but not when pollinated by 9 other species; discussion very weak: see Muntzing (1928)!
- & — (1975). Cytogenetic studies in the genus Potentilla L. New Phytol. 75:135-146.
- 18 x 18 species crosses, yielding 4 hybrid progenies. Very few intrasectional crosses tried; very simple discussion of hybridization in the genus.
- Ascherson, P. & Graetner, P., & Wolf, Th. (1904-1905). Potentilla (pars). in Ascherson & Graetner, Synopsis der mitteleuropaischen Flora, bd. 6, abt. 1: 664-872.
- Keys, short descriptions and literature, for European species (including adventives from North America). Description and keys to sections ("groups"): preview of Wolf (1908).
- Asker, S. (1969). An intergeneric Fragaria x Potentilla hybrid. Hereditas 64:135-139.
- 6x F. moschata f. X 2x Pentaphylloides fruticosa m. gives hybrids, appearing like Fragaria and all 4x, with low growth and no runners (as in F. moschata). Crosses attempted between F. and Potentilla s.str. all have failed, as have those with females Potentilla, Comarum, or Pentaphylloides.
- (1970a). Apomictic biotypes in Potentilla intermedia and P. norvegica. Hereditas 66:101-108.
- P. i. in European USSR, P. n. widespread in Europe and Asia: both introduced in N America, where P. n. has widely spread. P. i. 8x ± obligate apomicts; P. n. 10x largely apomictic with some sexuals. Hypothesis of P. i. being hybrid between P. n. & P. argentea discussed: no evidence to support it.
- (1970b). Apomixis and sexuality in the Potentilla argentea complex. I. Crosses with other species. Hereditas 66:127-144.
- (1970c). Apomixis and sexuality in the Potentilla argentea complex. II. Crosses within the complex. Hereditas 66:189-204.
- (1971). Apomixis and sexuality in the Potentilla argentea complex. III. Euploid and aneuploid derivatives (including trisomics) of some apomictic biotypes. Hereditas 67:111-142.
- & Fröst, S. (1970a). Chromatographic studies of phenolic compounds in apomictic Potentilla L. Hereditas 65:241-250.
- Biotypes of P. argentea, canescens, collina, tabernaemontani, crantzii, intermedia, norvegica, and Fragaria vesca; using TLC on leaves. Different spots seen in different species; however, differences noted between leaves from young and mature plants. All biotypes were apomictic.
- & — (1970b). The Potentilla collina problem — a chemotaxonomic approach. Hereditas 66:49-70.
- Biotypes of P. argentea, collina, tabernaemontani, crantzii: TLC on leaves; coefficients of similarity calculated for 16 of the biotypes, based on presence/absence of spots. This coefficient showed P. collina intermediate between P. tabernaemontani and P. argentea, probably closer to the former.

- & — (1972). Plant age and chromatographic pattern in Potentilla. Hereditas 72:149-152.
- P. argentea, canescens, & norvegica: TLC on leaves of plants grown in growth chambers at different ages (in months). Showed only moderate influence of age on chromatographic pattern, more quantitative (intensities). Greatest differences in early stages of growth (up to 3 months).
- Bate-Smith, E.C. (1962). Chromatography and taxonomy in the Rosaceae, with special reference to Potentilla and Prunus. J. Linn. Soc. Bot. 58:39-54.
- Argentina is distinctive, with myricetin & leucodelphin, from rest of family. There are chemicals distinguishing Wolf's Trichocarpae from Gymnocarpae; and also Graciles from other groups. Many species seen to have one or more constituents characterizing them.
- Borhidi, A. & Isépy, I. (1966). Statistical studies on Potentilla species. Acta Bot. Acad. Sci. Hung. 12:221-239.
- P. thyrsoiflora, related to P. collina; statistics of leaf pubescence, size, leaflet teeth and their sizes; in species complex. Discrimination analysis allowed P. leucopolitanoides to be separated definitely from P. leucopolitana but not from P. thyrsoiflora.
- Britikov, I.A. & Musatova, N.A. (1973). (Modelling of the stimulating effects of pollen during parthenogenesis of Potentilla argentea L.: effectiveness of proline). Fiziolog. Rast. 20:557-562. Translated as: Soviet Plant Physiology.
- Several chemicals induced seed-set greater than water control, but in every case, pollinated flowers set much greater seed than either. Of these chemicals, proline and the enzymes papain and amylase had the most striking inducement effect. Casein hydrolyzate, ATP, and arginine had significant effect. Plant growth substances, nucleotides, RNase, coconut milk, and glutamic acid all had no effect.
- Chaika, V.M., Sobolevskaya, K.A., & Minayeva, V.G. (1973). K chyemosistematike roda Potentilla L. Izv. Sibir. Otdel. Akad. Nauk SSSR ser. Biol. Nauk 2:31-36.
- 13 species of Potentilla of SE Altai Mts.: 4-7 flavenoids by paper chromatography. Limited study, but these may be useful to distinguish genera: Comarum, Potentilla s.str., Argentina.
- Challice, J.S. (1974). Rosaceae chemotaxonomy and the origins of the Pomoideae. Bot. J. Linn. Soc. 69:239-259.
- Leaf samples from 197 species, using paper chromatography. Only one Potentilla species used. Discussion of phylogeny of subfamilies, particularly v/v Pomoideae.
- Christoff, M. & Papasova, G. (1943). Die genetischen Grundlagen der apomiktischen Fortpflanzung in der Gattung Potentilla. Zeitschr. Vererbungsl. 81:1-27.
- 220 crosses attempted, mostly among species of Potentilla s.str.; 24 species crossed in all; 15 hybrid progenies obtained. All sexual x sexual crosses had sterile F₁s; most fertile F₁s yielded high proportion of maternal F₂.
- Clausen, J., Keck, D.D., & Hiesey, W.M. (1940). Experimental studies on the nature of species I. Effect of varied environments on western North American plants. Carnegie Inst. Wash. Publ. 520:1-452.
- Drymocallis glandulosa, pp. 26-124: taxonomic review, transplant studies, discussion; ecotypes formed all at diploid level. Potentilla gracilis complex, pp. 125-175: taxonomic revision, very high chromosome numbers and some aneuploids, transplant studies, discussion. P. drummondii and P. breweri,

- pp. 176-195, transplant studies, discussion, very high chromosome numbers, aneuploidy.
- & Hiesey, W.M. (1958). Experimental studies on the nature of species IV. Genetic structure of ecological races. *Carnegie Inst. Wash. Publ.* 615: 1-312.
- Srymocalis glandulosa*, pp. 1-156: crossing studies and detailed analysis of inheritance of characters, combined with transplant studies; all variation is at the diploid level. Tremendous amount of data: often cited, rarely digested.
- Dansereau, P. (1955). Studies in *Potentillae* of high latitudes and altitudes. *Trans. Roy. Soc. Canada Ser. III* 49:11-23.
- Summary of chromosome numbers in *Potentilla* recorded to date, arranged by Wolf's system.
- Ellis, J.R. (1962). *Fragaria-Potentilla* intergeneric hybridization and evolution *Fragaria*. *Proc. Linn. Soc. London* 173(2):99-106.
- females *F. ovalis* 8x 10x, *vesca* 2x 4x X males *P. erecta* 4x, *anglica* 8x, *fruticosa* cv. 2x, *palustris* 6x. Successful hybrids only with *Comarum* (*P. palustris*) and *Pentaphylloides* (*P. fruticosa*), none with *Potentilla* s.str.
- Hitchcock, C.L. (1961). *Rosaceae*, in *Vascular Plants of the Pacific Northwest*, part 3. Univ. Washington, Seattle, pp. 89-195.
- The only recent attempt at herbarium-based revision of (in this case, a geographical subset of) *Potentilla*. Conservative treatment, but more flawed as he tries to deal with taxa outside his field of experience (e.g., *Potentilla concinna* var. *rubripes*).
- Kalkman, C. (1968). *Potentilla*, *Duchesnea*, and *Fragaria* in Malesia. *Blumea* 16:325-354.
- Kania, W. (1973). *Entwicklungsgeschichte Untersuchungen an Rosaceenblüten*. *Bot. Jahrb.* 93:175-246.
- In 52 species (none from *Potentilla* s.str.). Polyandry is secondary in development, as is polygyny. Stamens are in whorls, pistils in cycles. Epicalyx (outer calyx) is probably emergent from the calyx. Epigyny results largely from raising of periphery, which in some cases is accompanied by a lifting of the floral axis. Floral development indicates close relationships: *Spiraeoideae*—*Maloideae* and *Spiraeoideae*—*Prunoideae*.
- Keck, D.D. (1938). Revision of *Horkelia* and *Ivesia*. *Lloydia* 1(1-4):75-142.
- These 2 genera endemic on Pacific slope of N America; distinguished from *Potentilla* by: stamens 5-15; filaments dilated or narrow; hypanthium; carpels few or many; petals clawed, yellow or white; leaves pinnate or verticillate-pinnate, with confluent upper leaflets; *Horkelia* with distinctive odor.
- Kohli, B.L. & Denford, K.E. (1977). A study of the flavonoids of the *Potentilla pensylvanica* complex in North America. *Canad. J. Bot.* 55:476-479.
- Paper chromatography. 3 species in Kohli & Packer (1976) surveyed for presence/absence of 11 flavonoids, of which 3 were diagnostic in various combinations, sufficient to differentiate the 3 species; however, see review of previous paper.
- & Packer, J.G. (1976). A contribution to the taxonomy of the *Potentilla pensylvanica* complex in North America. *Canad. J. Bot.* 54:706-719.
- Garden transplants from populations of this complex in W Canada showed 3 chromosome numbers: 2x, 4x, 8x, correlated with size of guard cells and of

pollen. Using these correlations, the 3 euploid races assigned to 3 different species. Other taxa and populations in this complex were not sampled or studied: they were ignored, but results were nonetheless extended to all of N America.

Lehmann, J.G.C. (1820). Monographia generis Potentillarum. Hoffmann, Hamburg, 201 pp.

Much more 19th century than Nestler (1816). Good commentary and very remarkably perceptive taxonomy, considering progress of exploration in 1820. Lehmann was 28 at the time; generally very careful, but he described *Potentilla arguta* twice, as 2 different species! All in Latin: total 88 spp.

— (1856). Revisio Potentillarum. Verh. Kaiserl. Leopold-Carolin. Akad. Suppl. 23:1-230.

Lehmann's last work in *Potentilla* after 36 years; he died in 1860. His very careful taxonomy was an inspiration to both Wolf and Rydberg. This book was used world-wide for over 50 years and is still a very useful reference, although largely superseded by Wolf (1908), q.v., who toiled at length over most of Lehmann's taxa and comments. Keys and descriptions in Latin, discussion and notes in German: total 201 spp.

Matfield, B. (1972). Potentilla reptans L. — identification of its hybrids. *Watsonia* 9:137-147.

Describes a natural tetraploid cross *P. repans* X *P. erecta* (see Matfield & Ellis 1972).

— & Ellis, J.R. (1972). The allopolyploid origin of Potentilla anglica. *Heredity* 29:315-327.

(= *P. procumbens* Leichardring). *P. erecta* and *P. reptans* are tetraploids; colchicine-induced 8x plants of these were crossed, giving hybrids very close to *P. anglica*. From genetic comparisons, they hypothesize: 4x P.r. X 4x P.e. gives 6x hybrid X 4x P.e. gives 8x *P. anglica*.

Müntzing, A. (1928). Pseudogamie in der Gattung *Potentilla*. *Hereditas* 11:267-283.

P. argentea, *P. collina*, & *P. tabernaemontani*: several biotypes of each set no seed when pollen was excluded; 36/62 of crosses among biotypes showed completely maternal progeny; 4/62 of these crosses had very few (1-3 each) hybrid individuals. The maternal F_1 s had maternal chromosome number.

— (1931). Note on the cytology of some apomictic *Potentilla*-species. *Hereditas* 15:166-178.

Additions to Müntzing (1928). Chromosome numbers in biotypes varied $2n = 14-84 = 2x-12x$. He showed that biotype 5x and hybrids between 2 different parents, show high degree of chromosomal heterozygosity through apomixis. Polyploids show multivalents at meiosis, leading to pollen sterility.

— (1958a). Further studies on interspecific polyploidy in *Potentilla argentea* (coll.). *Bot. Not.* 111(1):209-227.

Garden studies of different natural populations of *Potentilla argentea*: 2x, 4x, 6x; mostly from Blekinge, S Sweden. Many scattered 2x: very polymorphic; 6x most frequent polyploid; 4x restricted; 5x very rare. Correlations of polyploidy with: plant weight, duration of life, percent pollen sterility. All biotypes (even 2x) were strictly apomictic.

— (1958b). The balance between sexual and apomictic reproduction in some hybrids of *Potentilla*. *Hereditas* 44:145-160.

Hybrids produced between biotypes of *P. argentea*: 2x sexual (A-c) x 6x apomict gives 5x with complete range in F_1 between complete apomixis and

- complete sexuality. 2x sexual (A-C) x 2x apomict gives 2x uniformly sexual. 2x sexual (A-C) x 4x apomict gives 3x, with F₂ about equally sexual and apomictic. Concludes: mode of reproduction in apomict x sexual crosses determined not only by ratio of number of genomes, but also probably genetic.
- (1958c). Heteroploidy and polymorphism in some apomictic species of *Potentilla*. *Hereditas* 44:280-329.
- & Muntzing, G. (1941). Some new results concerning apomixis, sexuality, and polymorphism in *Potentilla*. *Bot. Not.* 1941:237-278.
- Within *P. argentea*: chromosome counts in 53 strains, each completely uniform, but different morphologically from one another. 2x annual-biennial, more northern distribution; correlations between ploidy and pollen diameter, seed diameter, per cent fertility of pollen, irregularity of meiosis.
- & — (1942). Recent results in *Potentilla*. *Hereditas* 28:232-235.
- Summary of previous paper.
- & — (1943). Spontaneous changes in chromosome number in apomictic *Potentilla collina*. *Hereditas* 29:451-460.
- In biotype C-A (6x), progenies showed two deviant 12x plants. But 10-42% of this 12x's progeny was 6x reversions.
- & — (1945). The mode of reproduction of hybrids between sexual and apomictic *Potentilla argentea*. *Bot. Not.* 1945:49-71.
- Summarized in Muntzing (1958b).
- Nestler, C.G. (1816). Monographia de Potentilla, praemissis nonnullis observationibus circa familiam Rosacearum. Treuttel & Wurtz, Paris, 80 pp.
- The first monograph of *Potentilla*; primitive, 18th century in scope. Essentially a literature survey, but notably includes new species of Humboldt & Bonpland from Mexico. All in Latin: total 68 species.
- Pawlowski, B. (1959). De positione systematica *Potentillae Doerfleri* Wetts. *Fragm. Florist. Geobot.* 5(3):399-407.
- Treat's Wolf's "Greges" as "Series".
- Popoff, A. (1935). "Über die Fortpflanzungsverhältnisse der Gattung *Potentilla*." *Planta* 24:510-522.
- 15 x 15 species crosses gives 2 hybrids and 20 maternal progenies. Species are poorly identified, and their sources not indicated; many of his reported chromosome numbers have not been verified.
- Rutishauser, A. (1943a). "Über die Entwicklungsgeschichte pseudogamer *Potentillen*." *Arch. Julius Klaus-Stift.* 18:687-691.
- (1943b). Untersuchungen über die Fortpflanzung und Bastardbildung apomiktischer *Potentillen*. *Ber. schweiz. bot. Ges.* 53:5-83.
- (1943c). Konstante Art- und Rassenbastarde in der Gattung *Potentilla*. *Mitteil. naturforsch. Ges. Schaffhausen* 18:111-134.
- (1945a). Zur Embryologie amphimiktischer *Potentillen*. *Ber. schweiz. bot. Ges.* 55:19-32.
- (1945b). Über die Fortpflanzung einiger Bastarde von pseudogamen *Potentillen*. *Arch. Julius Klaus-Stift.* 20(suppl.):300-314.
- (1946). Über Kreuzungsversuche mit pseudogamen *Potentillen*. *Arch. Julius Klaus-Stift.* 21:469-472.
- (1948). Pseudogamie und Polymorphie in der Gattung *Potentilla*. *Arch. Julius Klaus-Stift.* 23:267-424.

- (1949). Untersuchungen über Pseudogamie und Sexualität einiger Potentillen. Ber. Schweiz. bot. Ges. 59:409-420.
- (1954). Weitere Beiträge zur Genetik der Aposporie pseudogamer Potentillen. Arch. Julius Klaus-Stift. 29(3/4):223-233.
- (1960). Untersuchungen über die Evolution pseudogamer Arten. Ber. Schweiz. bot. Ges. 70:113-125.
- Rydberg, P.A. (1896). Notes on Potentilla. I. Bull. Torrey Bot. Club 23:244-248; II. op.cit. 23:259-265; III. op.cit. 23:301-306; IV. op.cit. 23:394-399; V. op.cit. 23:429-435. (1897) VI. op.cit. 24:1-13.
- (1898). A Monograph of the North American Potentilleae. Mem. Dept. Bot. Columbia Univ. 2:1-223.
- Complete literature, descriptions (shortened for Mexican species). 124 species in Potentilla s.lat., of which 106 in Potentilla s.str. Treatment reasonable, but published just before considerable exploration, especially of W North America.
- (1908). Rosaceae: Potentilleae, in North American Flora 22(3/4):268-377.
- Rydberg's last systematic work in this genus. 215 species in Potentilla s.lat., of which 176 are in Potentilla s.str. Generic concepts just now gaining favor; species distinctions almost useless (based on "unit characters") and his system for Potentilla has been justly ignored. Many sections have exactly the same descriptions as in 1898, but there are 70 new species!
- (1910). Notes on Rosaceae. III. Bull. Torrey Bot. Club 37:375-386; IV. op.cit. 37:487-502; (1911). V. op.cit. 38:79-89.
- Discussion of genera and their types: type of Potentilla is P. reptans L. (accepted by all subsequent workers). Notes that Wolf (1908) antedates Rydberg (1908); the rest is a half-hearted review of Rydberg (1908) in comparison with Wolf (1908), with some minor notes and adjustments.
- Sax, K. (1931). The origin and relationships of the Pomoideae. J. Arnold. Arb. 12:2-22.
- Summary of chromosome numbers in Rosaceae; discussion of cytology, especially as regards Pomoideae, in which $x = 17$. Consideration of reproduction in family leads to hypothesis about evolution of subfamilies.
- (1933). The origin of the Pomoideae. Proc. Amer. Soc. Hort. Sci. 30:147-150.
- Summary of Sax (1931); no data presented.
- Sorokina, T.P. (1974). Morfologicheskoye i tsitologicheskoye izucheniye potomstva F_1 ot skreshchivaniya mezdu razlichnymi vidami Potentilla. In Petrov, D.F., ed., Apomikticheskoye Razmnozheniye i Geterozis. "Nauka", Novosibirsk, pp. 155-161.
- Morphological and cytological investigations of the F_1 progeny from hybridization among various species of Potentilla, from the book, Apomictic Reproduction and Heterosis.
- Troll, W. (1935). Vergleichende Morphologie der Fiederblätter. Nova Acta Leopold. bd. 2, abt. 3/4(4):315-455.
- Comparative morphology of pinnate leaves, based on developmental studies. He differentiates between basipetal-pinnate, acropetal-pinnate, and divergent-pinnate leaves; very complete discussion of many cases.
- Watson, S. (1873). Revision of the extra-tropical North American species of the genus Potentilla (excluding Sibbaldia, Horkelia, and Ivesia). Proc. Amer. Acad. Arts Sci. 8:549-573.

Very simplistic; many mergers of taxa on the basis of gross similarities. Only 33 species!

Wolf, Th. (1908). Monographie der Gattung Potentilla. Bibl. Botan. 16(71):1-714.

The last world-wide monograph of the genus. Generally very careful, very complete descriptions of all taxa; reduces many of Rydberg's species to varieties or forma. Conservative concept, following Lehmann (1856); European species very well studied, but he was forced to accept many of Rydberg's taxa, because of lack of communication between these two great workers in this genus, and because of Wolf's lack of field knowledge in N America. Very complete discussion of Lehmann's works; if this book has a fault, it might be an over-zealous dedication to Lehmann's opinion. Keys and descriptions in (very straightforward) Latin, discussion and introductions in German: 305 species, of which 101 have ranges in New World. Includes Argentina, Comarum, Pentaphylloides, Drymocallis, and Sibbaldiopsis in Potentilla.

Wulff, E. (1909). Über Pollensterilität bei Potentilla. Österr. bot. Zeitschr. 59:415-424.

Many low counts found; discussion of the possible reasons.

Yuzepchuk, S.V. (1941). Rosaceae: Potentilleae, in Flora SSSR 10:59-223. Translated by Israel Program for Scientific Translations, 1971.

Accepts Fragaria, Duchesnea, Pentaphylloides (Dasiphora), Comarum, Potentilla, Sibbaldia, all as genera. In Potentilla, includes Drymocallis and Argentina. Defines new subgeneric names. Generally changes Wolf's "Geges" to "Sections". Original in Russian with new species in Latin; translation with text in English: 147 species in Potentilla.

Zhitkov, V.S. (1972). K evolyutsii lista v rodye lapchatka (Potentilla L.) Izv. Timiryazhev. Sel'skikhkhkh. Akad. 5:43-52.

On the evolution of leaves in Potentilla. Original leaf in Rosaceae was probably simple; basipetal-pinnate dissection led to the typical leaf in Geum and Filipendula; this was then the primitively original leaf in Potentilla, which fairly soon lost all but the terminal leaflet. This terminal leaflet dissected into ternate by acropetal growth. From that, there are several lines which could give: pinnate leaves acropetally, pinnate leaves basipetally, or by both processes. Digitate leaves in this genus are generally earlier than pinnate, but not necessarily ancestral to them.

1. Rosoideae (x = 7)

- Acaena
- * Acomastylis
- A Agrimonia
- * Argentina
- Aruncus (& x = 9)
- Bencomia
- Coluria
- * Comarum
- Dendropoterium
- * Drymocallis
- * Duchesnea
- * Filipendula (& x = 8,9)
- * S Fragaria
- * S Geum
- Hesperhodos
- Hulthemia
- Marcetella
- S Neviusia (& x = 9)
- Novosieversia
- * Pentaphylloides
- Platyrhodon
- *AS Potentilla
- Poterium
- Pygeum
- * S Rosa
- *AS Rubus
- * Sanguisorba
- * Sieversia
- * Waldsteinia

2. Prunoideae (x = 8)

- @*AS Alchemilla (Rosoideae)
- Amygdalus
- Aphanus
- Armeniaca
- * Cerasus
- @ Exochorda (Spiraeoideae)
- * Lachemilla
- Maddenia
- Padus
- Persica
- Prinsepia
- * S Prunus
- Osmaronia (& x = 6)

3. Spiraeoideae (x = 9)

- Aruncus (& x = 7)
- Cercocarpus
- Cowania
- @ Dryas (Rosoideae)
- Fallugia
- Gillenia
- S Kerria
- Luetkea
- Neviusia (& x = 7)
- Pentactina
- Physocarpus
- Purshia
- @ Rhodotypos (Rosoideae)
- Sibiraea
- Sorbaria
- * Spiraea

4. Pomoideae (x = 17)

- * Amelanchier
- Aronia
- S Chaenomeles
- *A Cotoneaster
- *A Crataegus (& x = 8)
- S Cydonia (& x = 8)
- S Eriobotrya (& x = 8)
- *AS Malus
- Mespilus
- Osteomeles
- * Photinia
- Pyracantha
- * S Pyrus
- Quillaja
- Raphiolepis
- *A Sorbus
- Stranvaesia

Subfamilies and chromosomally known genera of Rosaceae, grouped by apparent basic chromosome number (x). @ = genus traditionally assigned to a different subfamily (shown in parentheses); * = polyploids known in addition to diploids; A = apospory and parthenogenesis known; S = sexual outcrossing forms known. If other basic chromosome numbers are shown, these are listed in parentheses. Rearranged from data in Bolkhovskikh 1969, Sax 1931, Tischler 1957, and Grant 1971, with additions from various sources.

Table 7. Test-crosses performed on recombinant diploids of A-A (see text)

	× A-C	× "Bickings"	× intermediate
No. of plants crossed	30	30	30
No. of plants with seed set	25	24	569
Total number of seeds	3,265	1,993	1,000
Seeds per plant (3 flowers) crossed	129	80	19
Seeds per plant with seed set	131	81	52
Number of seeds/ear	412	157	17
Number of seedlings	402	146	34
Percentage of germinated seeds	29.2	79	47.2
Number of mature plants	61.8	7.3	6.5
Percentage of seedlings surviving to maturity	14.9	24.9	32
Percentage of seeds giving mature plants	16.8	64	94.1
Mature plants: maternal	269	81	0
" hybrids	6.2	1	0.0
" uncertain or unknown	5.5	8.9	2.9
uncertain or unknown	1.7	10.1	5.9

Table 3. Comparison between different recombined diploids concerning the composition of progenies from test-crosses (see text)

Plant	X-A-C				X-Blinkings				X-intermedia			
	M	H	?	Total	M	H	?	Total	M	H	?	Total
1 (i 120 A)				0	2			2				0
2 (i 120 B)	2	18		20			1	19				0
3 (i 125 A)	2	5		7	13	1		14				0
3 (i 125 A)		2		2					2			2
4 (i 127 A)					1			1	13			13
5 (i 127 B)		4	4	4								0
6 (i 128 A)				3				0				0
7 (i 133 A)	1	2		3				0				0
8 (i 133 B)	1	43		44					2			2
9 (i 133 C)	1	24		25					5			5
10 (i 133 D)		25		25								0
11 (i 136 B)		23	1	24				0				0
12 (i 136 C)		23		23	5			5	5			5
13 (i 137 A)		34		34	15	3		18				0
14 (i 139 A)		9		9	2	1		3				0
15 (i 140 A)		30		30	6			6				0
16 (i 140 B)	1	30		31	7			7	5			5
17 (i 152 A)	3	15		18	7			7			1	1
18 (i 160 A)	3	11		14					4			4
19 (i 161 A)				1	2	1		3				0
20 (i 170 B)	1			5	2	1		3				0
21 (i 171 A)		8		8				0				0
22 (i 173 A)	1	12		13								0
23 (i 174 A)		5	2	7	64	7	8	79				0
Total	18	269		29	12			12				not crossed
Diploid A-A	5	24		29								

APOMIXIS AND SEXUALITY IN *POTENTILLA* III 127

TETRAPLOID ($2n=28$)
"BLEKINGE" (2:A)
c. 99 % apomictic
c. 1 % aberrants (mainly B_{III} hybrids
and chr. doubled plants)

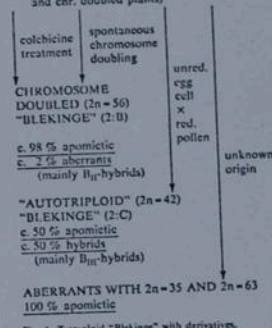


Fig. 6. Tetraploid "Blackies" with derivatives.

ROSACEAE CHEMOTAXONOMY AND THE POMOIDEAE

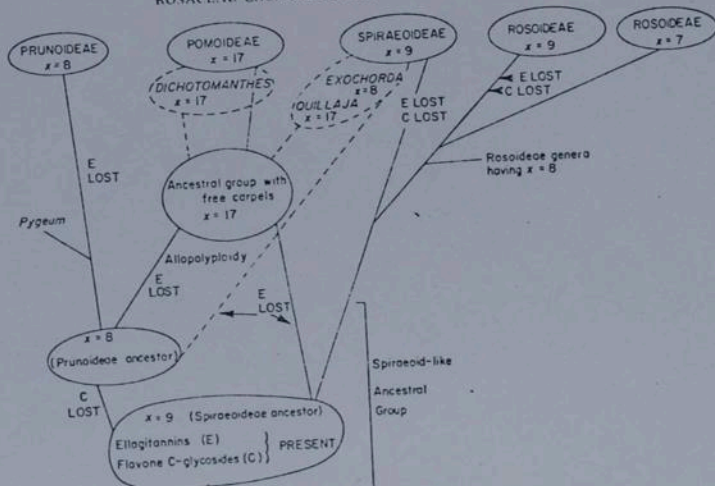


Figure 2. Hypothetical scheme for the evolution of Rosaceae subfamilies.

Key to the genera of Rosaceae-Potentilleae-Potentillinae (after Wolf 1908)

1 Achenes 5- ∞ (rarely 3-6); stamens 5- ∞ .

2 Stamens 10- ∞ ; achenes mostly ∞ . (In Potentilla pentandra filaments only 5, but then achenes ∞).

3 Calyx low and broad, plate- or bowl-shaped; stamens attached close to the base of the carpophore, on the $\pm$ thickened border of a nectariferous disk

4 Carpophore when ripe fleshy, this loosening and falling from the calyx Fragaria

4 Carpophore when ripe either dry or spongy, rarely fleshy, but then not loosening, rather remaining attached . . Potentilla

3 Calyx funnelform or pitcher-shaped, without thickened nectariferous disc; stamens attached away from the base of the carpophore

. . . Horkelia (incl. Ivesia)

2 Filaments 5 (very rarely 10); achenes 5-15 (the few Potentillas with only five filaments always have numerous achenes).

3 Outer calyx well-developed, calyx as in Potentilla

. . . Sibbaldia

3 Outer calyx undeveloped, or represented by long bristles; calyx as in Horkelia Chamaerhodos

1 Achenes 2; stamens 5; calyx funnelform, with flat margin

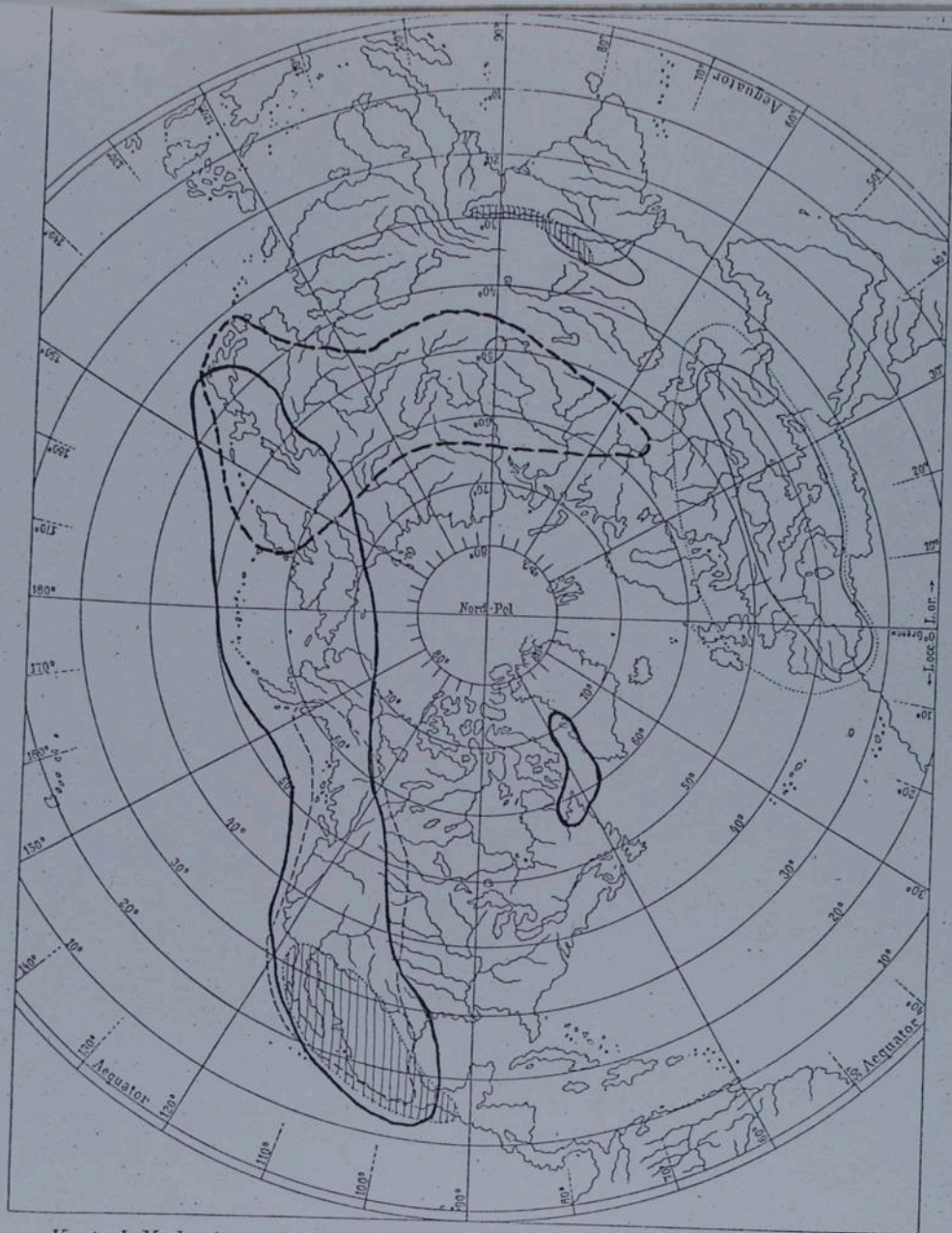
. . . Comarella

1 Achenes 1; stamens 15; anther-sacs opening by a pore above; calyx funnelform, as in Horkelia Stellariopsis

Key to the genera of Rosaceae-Potentilleae (after Rydberg 1908)

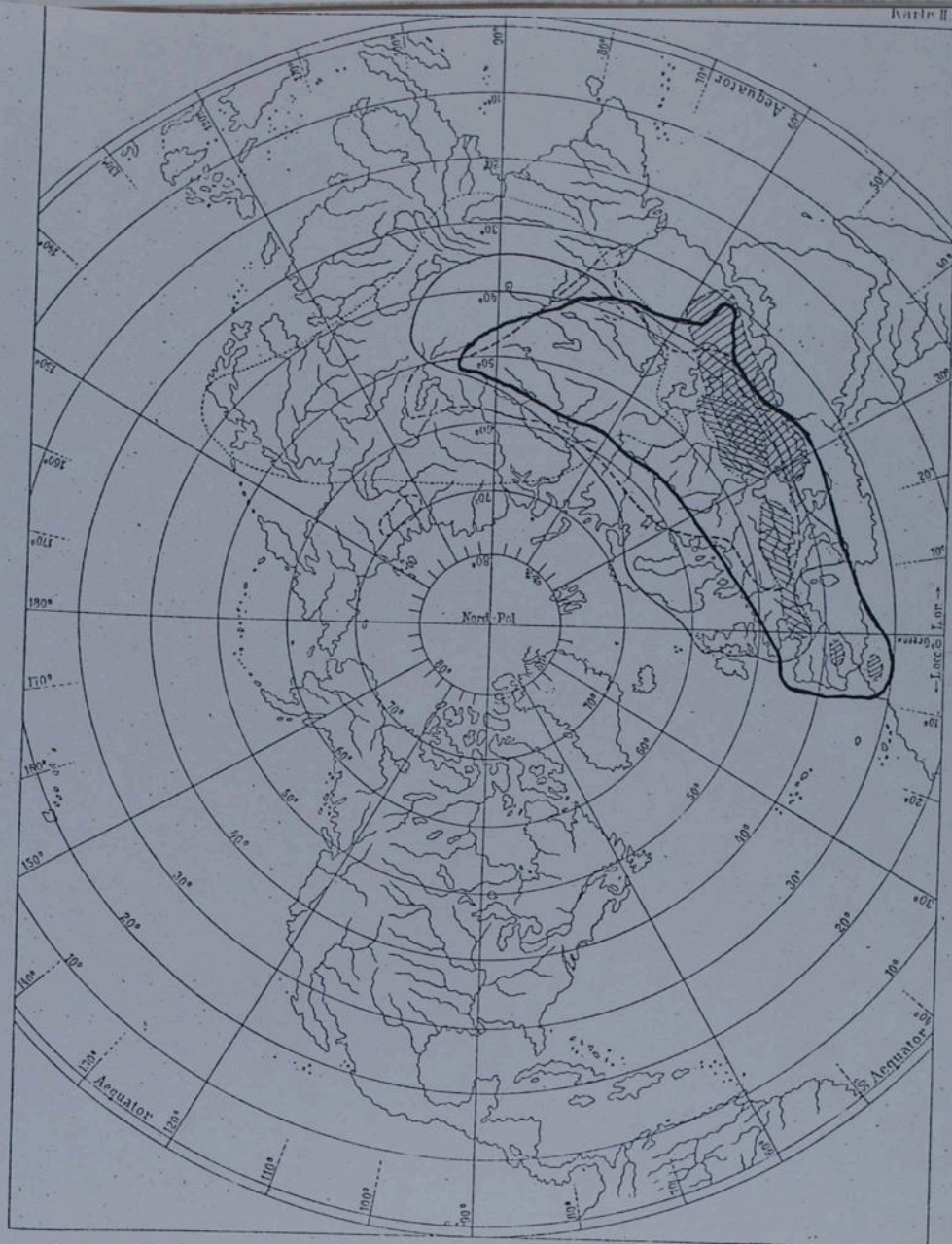
- 1 Style terminal or nearly so; ovules ; ovules pendulous and anatropous
 - 2 Anthers oblong, opening by longitudinal slits; pistils two to many
 - 3 Stamens separated from the receptacle by an open space; no indication of an annular thickening at the base of the filaments
 - 4 Hypanthium saucer-shaped to deeply campanulate; petals oblanceolate to obcordate or cuneate; pistils usually more than 2
 - 5 Filaments dilated, petaloid
 - 6 Stamens 10; sepals not reflexed in anthesis . . . *Horkelia
 - 6 Stamens 20
 - 7 Pistils numerous; hypanthium campanulate; sepals reflexed in anthesis *Horkeliella
 - 7 Pistils 3-6; hypanthium turbinate; sepals not reflexed in anthesis *Ivesia
 - 5 Filaments filiform
 - 6 Pistils inserted in the bottom of the hypanthium; bractlets present *Ivesia
 - 6 Pistils inserted on a stalked receptacle; bractlets lacking *Purpusia
 - 4 Hypanthium wheel-shaped; petals narrowly linear; pistils 2 *Comarella
 - 3 Stamens inserted very near the base of the receptacle on a more or less evident annular thickening POTENTILLA
 - 2 Anthers obcordate, opening by subterminal pores; pistil 1 . . *Stellariopsis
- 1 Style lateral; ovules ascending and amphitropous
 - 2 Achenes glabrous; herbs
 - 3 Achenes numerous; stamens about 20
 - 4 Leaves odd-pinnate
 - 5 Receptacle not enlarged in fruit; petals yellow, obtuse or retuse; leaves interruptedly pinnate (Argentina)
 - 5 Receptacle somewhat enlarged in fruit, becoming spongy; petals red, acute or acuminate; leaves regularly pinnate (Comarum)
 - 4 Leaves trifoliolate; receptacle much enlarged and usually red in fruit
 - 5 Receptacle not pulpy; petals yellow (Duchesnea)
 - 5 Receptacle pulpy; petals white or pinkish *Fragaria

- 3 Achenes 10-15; stamens 5; leaves trifoliolate *Sibbaldia
- 2 Achenes hairy; shrubs or undershrubs
 - 3 Style filiform; leaves trifoliolate; petals white (Sibbaldiopsis)
 - 3 Style club-shaped; leaves pinnate; petals mostly yellow (Pentaphylloides)
- 1 Style nearly basal; ovules ascending or nearly erect, orthotropous
 - 2 Stamens and pistils numerous; bractlets present; leaves pinnate (Drymocallis)
 - 2 Stamens 5; bractlets wanting; leaves twice- or thrice-ternate (Chamaerhodos)



Karte I Verbreitung der Gattung *Potentilla* und einzelner Gruppen derselben

- | | | |
|---|--|--|
| — Allgemeine Verbreitung. | — <i>Trichocarpae herbaceae</i> (exceptis <i>Fragariastris</i>) | — Gr. <i>Multijugae</i> et <i>Ranunculoideae</i> . |
| Gr. <i>Fragariastris</i> (<i>genuina</i>) | | --- Gr. <i>Graciles</i> . |
| --- Gr. <i>Fragarioides</i> . | | Gr. <i>Haematocarpa</i> . |



Karte II Verbreitung der Gattung *Potentilla* und einzelner Gruppen derselben

- | | | |
|-------------------------|------------------|-------------------|
| Allgemeine Verbreitung. | Gr. Argenteae. | Gr. Rectae. |
| Gr. Persicae. | Gr. Chrysanthae. | Gr. Grandiflorae. |
| Gr. Tanacetifoliae. | | |

P.L.	2n	1										2										3											
		1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	
16	112																																
15	105																																
14	98																																
13	91																																
12	84																																
11	77																																
10	70																																
9	63																																
8	56																																
7	49																																
6	42																																
5	35																																
4	28																																
3	21																																
2	14																																

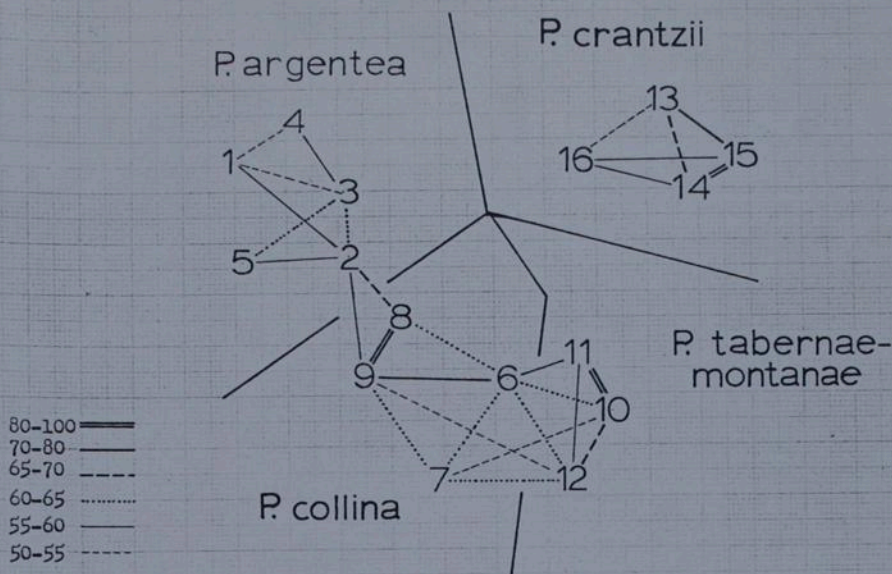
Recorded chromosome numbers in *Potentilla s.lat.* Numbers across are numbers of the Groups (Greges) in Wolf (1908), listed in following table. Numbers shown between Ploidy Levels (P.L.) means that aneuploid numbers have been recorded for those groups. Data from Bolkhovskikh (1969), and a variety of other sources.

Group ("Grex") (after Wolf 1908)		Genus Name (after Rydberg 1908)
Number	Name	
1	Fruticosae	<u>Pentaphylloides</u> (Rydberg calls it <u>Dasiphora</u>)
2	Bifurcae	
3	Xylorhizae	<u>Trichothalamus</u>
4	Biflorae	
5	Pallustres	<u>Comarum</u>
6	Tridentatae	<u>Sibbaldiopsis</u>
7	Eriocarpae	
8	Speciosae	
9	Nitidae	
10	Curvisetae	
11	Crassinerviae	
12	Caulescentes	
13	Fragariastra	
14	Rupestres	<u>Drymocallis</u>
15	Multifidae	
16	Graciles	
17	Haematochroae	
18	Niveae	
19	Argenteae*	
20	Tanacetifoliae	
21	Rectae	
22	Rivales	
23	Persicae	
24	Grandiflorae	
25	Chrysanthae	
26	Multijugae	
27	Ranunculoides	
28	Aureae	
29	Fragarioides	
30	Tormentillae	
31	Anserinae	<u>Argentina</u>

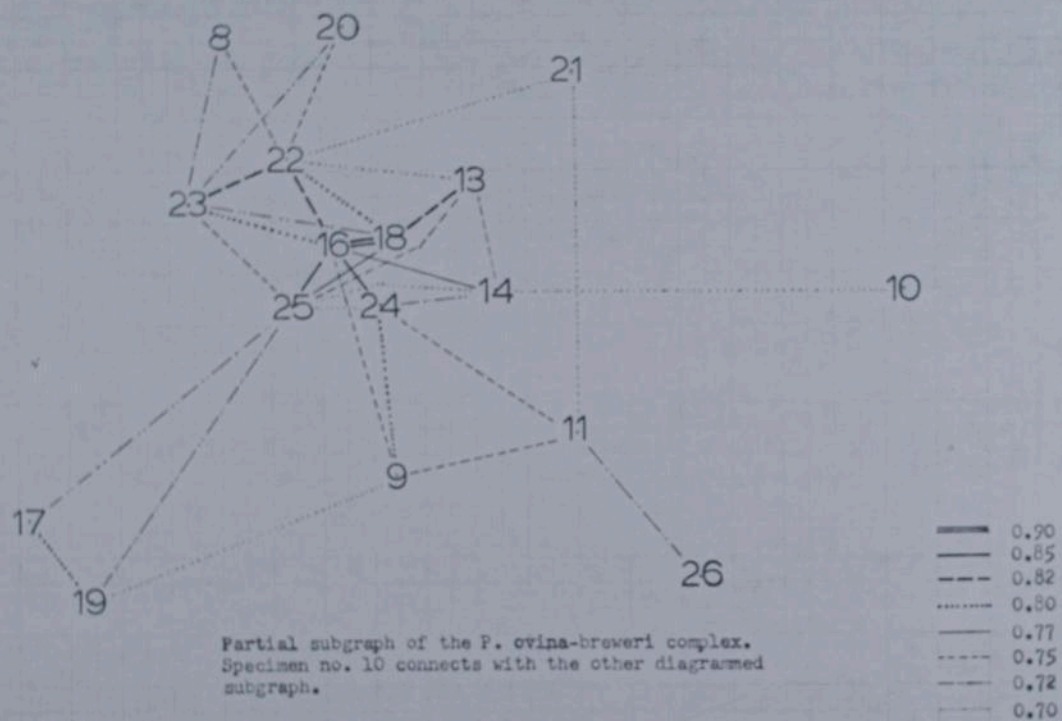
* including Collinae

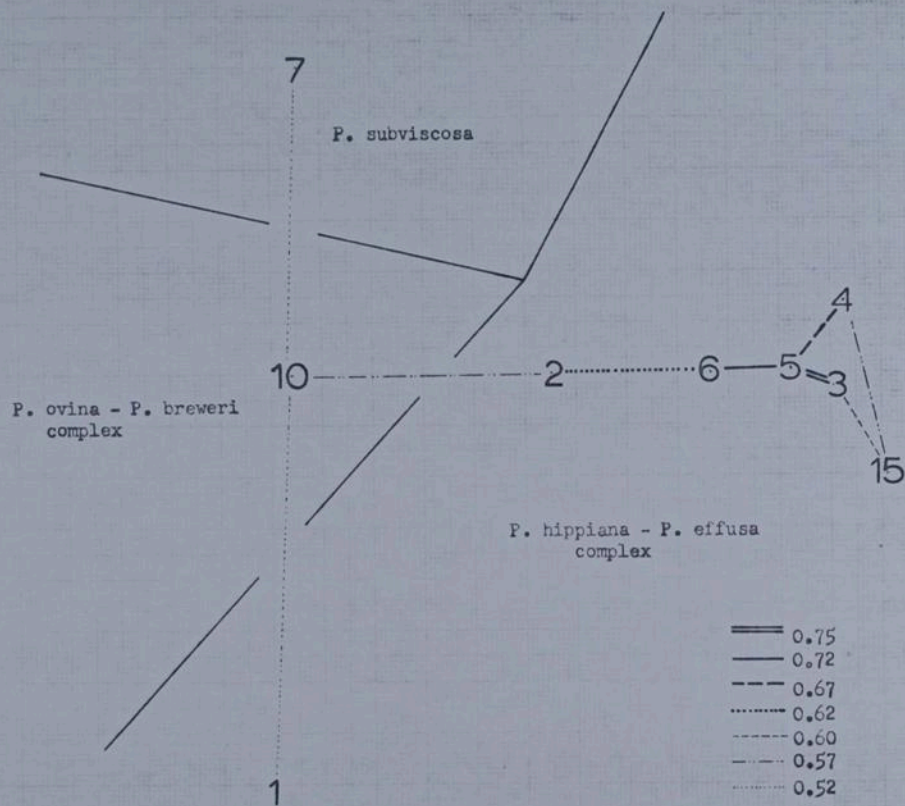
	<u>Pentaphylloides fruticosa</u>		<u>Comarum palustre</u>		<u>Comarum salesovianum</u>		<u>Potentilla bifurca</u>		<u>Potentilla biflora</u>		<u>Potentilla multifida</u>		<u>Potentilla seisea</u>		<u>Potentilla nivea</u>		<u>Potentilla astragalifolia</u>		<u>Potentilla chrysantha</u>		<u>Potentilla gelida</u>		<u>Potentilla gelida</u>		<u>Argentina anserina</u>	
	leaves	flowers	leaves	flowers	leaves	flowers																				
	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6										
Isorhamnetin.....						0			0	0	0	0	0	0	0	0										
Kaempferol.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										0
Quercetin.....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										0
Myricetin.....																										0

Table showing the aglycones in the plant-parts of species of Potentilla of the south-eastern Altai Mountains (translated from Chaika et al. 1973)



Subgraph of relationships among 16 biotypes of *Potentilla*, based on thin-layer chromatography of their leaves. The metric used is the coefficient of similarity $C_s = p/(p + d)$, where p = number of positive matches (spots on chromatogram in common), and d = number of differences (spot present in one but not the other). Coefficients of similarity are only shown if they are 50% or greater; lines drawn between biotypes indicate their calculated coefficients of similarity. Drawn from data reported in Asker & Frøst (1970b).





Partial subgraph of the *P. hippiana* - *P. effusa* complex;
specimen no. 10 connects with the other diagrammed
subgraph.

UNIVERSITY OF COLORADO
AT
BOULDER, COLORADO 80309

Department of Environmental,
Population and Organismic Biology

February 16, 1979

Personnel
U. S. Forest Service
Lakewood, Colorado 80225

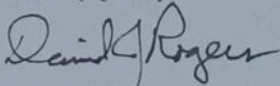
Gentlemen:

It is my understanding that a letter is required to indicate my approval of the suggested relationship between you and Mr. Barry Johnston. Mr. Johnston has explained that relationship as one in which he is employed by you on an "as available" basis. It is my further understanding that Mr. Johnston is to be allowed to set the number of hours under the "as available" basis. This is agreeable to me.

I am certain that Mr. Johnston has told you that I want him to devote nearly his full time to the pursuit of his doctorate degree under my direction. This is necessary so that he may complete his work in a reasonable time. I trust that you can understand that this is important both to Mr. Johnston and to the University of Colorado.

Furthermore, I trust that you know that both Mr. Johnston and I appreciate the kind offer you have made. I am pleased to know that he has provided satisfactory service to you in the past, and I am glad that you have offered an opportunity for him to maintain an official connection with the Forest Service. Yours, and his, work is vital, and I am glad to support him in a way you find agreeable.

Sincerely yours,



David J. Rogers
Professor of Biology
Advisor to Mr. Johnston

1250 18th St. Apt. 1
Boulder, Colorado 80302
January 25, 1978

Chairman, Graduate Committee
Department of E. P. O. Biology
Ramaley Hall
University of Colorado
Boulder, Colorado 80309

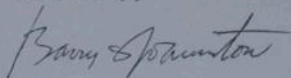
In a letter to Dr. David J. Rogers, the chairman of my degree committee, your committee stated that I would be admitted to the graduate program, if I passed the Graduate Record Examination's Advanced Biology Test at the 75th percentile, before the end of the Fall semester of 1977.

You should already have received notice of my results on this test, which I took in October, 1977, which indicates that I passed this test at the 84th percentile.

Therefore, please consider this letter as my application to you, to be admitted to the graduate program in your department.

Thank you very much.

Sincerely,



Barry C. Johnston

cc: Dr. David J. Rogers

UNIVERSITY OF COLORADO
AT
BOULDER, COLORADO 80309

Department of Environmental,
Population and Organismic Biology

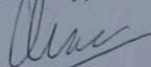
May 17, 1977

Dr. David Rogers
Hale 114
Campus

Dear Dave:

Thank you for your letter. We shall allow Barry Johnston one more chance to remove his deficiency. Accordingly, he must take the advanced portion (Biology) of the GRE and score at, or above, the 75th percentile level by the end of Fall Semester, 1977. If he does not, then he will have to be dropped from the graduate program in EPOB. He was delinquent because he did not meet the requirements set by Carl Bock and this will have to be his last chance.

Sincerely,



Marc Bekoff
Chairman, Graduate Program Committee

MB:eo

cc: Barry Johnston
Barry Johnston file

Department of Environmental,
Population and Organismic Biology

May 17

Dear Mark:

In response to yours of 5/13, re
Bary Johnston - please do not
cut him off! It would be
very damaging to him, to me, and
to the dept.

If you need any supporting
documentation of this I will give
you all kinds of bases for a
positive decision -

Dave Rogers

UNIVERSITY OF COLORADO
AT
BOULDER, COLORADO 80309

Department of Environmental,
Population and Organismic Biology

May 13, 1977

Dr. David Rogers
Hale 114
EPO Biology

Dear Dave:

I am unable to remove Barry Johnston from provisional status because he did not fulfill the requirements set forth by Carl Bock and the graduate committee, namely, that he re-take the Graduate Record Examination and score above the 75th percentile on all three parts. In fact, he was supposed to remove the deficiency by the end of Spring 1976.

Could you please inform the Graduate Program Committee (through me) whether or not you think he should be allowed another chance to meet the requirement (s) by the end of the Fall 1977 semester. If you do think that he deserves another chance, then the Graduate Committee will consider your request not to terminate him at our next meeting. However, if we do allow him to stay, the deficiency must be removed by the end of the Fall 1977 semester. Also, he should have taken the Ph. D. preliminary exam by the end of the Fall 1977 semester, as well.

If you have any questions, please let me know.

Sincerely,



Marc Bekoff,
for the Graduate Committee

MB:ea

Thesis proposal: Variation in the pinnate-leaved species of Potentilla L.
in the southern Rocky Mountains

Potentilla L. is taken in the strict sense (Rydberg 1898, 1908), and for convenience, the odd-pinnate species of that genus in the mountains of Colorado, eastern Wyoming, northern New Mexico (and possibly parts of Utah and Arizona) are chosen for study. The segregation of pinnate- from digitate-leaved plants is made largely for convenience, since it is realized that there is no clear division between the two. The two dissection patterns probably have the same ontogeny, and differ in the spacing of the leaflets; in a few "digitate"-leaved forms with five leaflets, the two lower leaflets are separated from the upper ones by a rachis which may be short or the length of the petiole. However, most forms are either obviously pinnate- or digitate-leaved, which makes the distinction a workable one at least. The relative functions of the two types of leaves are unknown; one conjecture would relate pinnate leaves with a more prostrate habit. This question could be made a small part of the this investigation, since several forms show a transition between the two types of leaf.

The first part of the project would consist of a survey of the taxonomic and genetic literature on Potentilla, both classical and modern, towards the end of trying to define a group within Potentilla that would in some way be natural, while still keeping the group under study small enough that the study can be completed within the time limit. This part of the project would necessarily include herbarium studies, and a mathematical estimation of affinities within the genus, and characters that might be of use in further stages of the project. This part of the project would also have as one of its

goals the identification of sites that would be valuable in terms of field and laboratory studies.

Data collection from herbarium specimens could include recording of the following descriptors:

1. locality
2. date and collector
3. root type
4. stem inclination
5. stem vesture
6. stem length (internode length?)
7. leaflet number
8. leaflet dissection
9. leaf vesture: upper/lower
10. flower size (petal size)
11. petal shape
12. sepal size (shape?)
13. bract shape (relative size?)
14. number of pistils (size?)
15. stamen length (incl. filament)
16. pollen size/polymorphism

In Potentilla, the basic haploid chromosome number is $x = 7$, but diploid ($2n$) numbers have been reported from species with pinnate leaves in Colorado, from $2n = 28$ up to $2n = 109$. Although the mode of reproduction of these Rocky Mountain species has not been studied in any detail, similar species in Europe (P. argentea complex) have been found to be commonly polyploid and apomictic, the two modes frequently combined within the same individual. There is evidence for a balance between the two modes (Müntzing 1958). In addition, the Rocky Mountain forms, like the European ones, frequently hybridize.

The apparently easy hybridization between forms, combined with capacity for asexual-clonal reproduction, should lead to the formation of many "microspecies" in a local area. Similar "microspecies" may arise in widely separated areas. A few herbarium specimens cannot adequately represent the complexity of such a system, for (even if they are presumed to be collected at random) one specimen probably represents only

Rydberg, F.A. 1898. Monograph of North American Potentilleae. Mem.
Dept. Bot. Columbia Univ. 2.

----- 1908. Rosaceae: Potentilleae, in North American Flora.
22:268-377.

Barry C. Johnston

1. Outline of program tentative

1st term - (Fall '77?) as A&P

2nd [Leave work
in] [Tentative approach problem work]

Comp.

Thesis work.

Final

2. Subjects included in Field of work

1. Botany

2. Ecology

3. Plant, Morphology / Hybrid / Plants

4. Taxonomy & Systematics

5. Taxonomy & Systematics

6. General Work

(To fill deficiencies?)

(Other?)

3. Thesis

one "microspecies" of many in a local area. This one specimen may be found to compare with a form from another area, which reasoning has led in the past to the two being placed in the same taxon. This process, even though representative of reality in many plant groups, only obscures and confuses the truth in groups such as the proposed subject.

After critical areas have been identified, and the complex of species to be studied has been defined, these critical areas can then be sampled. This phase, and the analysis resulting from these data, should take up the majority of time. These samples should be taken such that the intra- and inter-population structure will be revealed, in order that the questions can be answered:

1. Does the predicted pattern (Babcock & Stebbins 1938, Grant 1971) for apogametic complexes hold in this case? I.e., what is the geographical pattern of variation in morphological and karyological characters?

2. How does the observed pattern of variation between and within samples fit into a taxonomic framework that is workable and has utility?

To fit these purposes, a sample of 60 to 100 plants could be scored for each site; perhaps they could be arrayed along a transect, so that the geographical variation would be apparent.

The study should be complemented by laboratory investigation of the mode of reproduction of greenhouse plants selected from critical sites, through test crosses (limited by time, since most species in this group are perennial), and studies into the regulation of growth of leaf form.

Literature cited

- Babcock, E.B. & Stebbins, G.L. 1938. The American species of Crepis. Carnegie Inst. Wash. Publ. 504.
Grant, Verno. 1971. Plant Speciation. Columbia Univ. Press.
Müntzing, A. 1958. The balance between sexual and apomictic reproduction in some hybrids of Potentilla. Hereditas 44:145-60.

UNIVERSITY OF COLORADO
AT
BOULDER, COLORADO 80309

Department of Environmental
Population and Organismic Biology

February 16, 1977

To Whom It May Concern:

I am the chairman of the Ph.D. advisory committee for Barry C. Johnston at the University of Colorado.

I understand that Barry has been offered a position for the coming summer with the U.S. Forest Service, Rocky Mountain Region. His duties and responsibilities would include: identification of areas within the National Forests in this region that contain Endangered plant species, or those areas that are sensitive in that they contain populations of plants which might become rare and endangered; making Forest Service personnel aware of such species and areas, so that proper management decisions may be made; and cooperating with other institutions, agencies, and organizations interested in plants to achieve a better knowledge of the plants of the National Forests of this region.

I have read section 213.3102(p) of the Federal Personnel Manual, in which are described the qualifications that should be met when a graduate student fills such a position, and I agree that Barry meets the requirements; his position with the Forest Service, Rocky Mountain Region, would certainly be used by him as a portion of his requirements for the degree he is pursuing.

At the end of this semester, Barry will have completed two full years of work at this University at the graduate level.

Sincerely,

David J. Rogers
Professor of Biology

DJR:js

Potentilla L. is a genus of the Rosaceae-Rosoideae-Potentilleae. This tribe is distinguished by having fruit in the form of dry achenes with articulated styles, which are not closely invested or enclosed by the low hypanthium. Within the Potentilleae, there are around 18 genera, among which Potentilla is characterized by its terminal or subterminal style, longitudinally-opening anthers, and basal insertion of stamens. The generic concepts within Potentilleae as presented by Rydberg (1898, 1908) are generally accepted by most modern workers (e.g., Yuzepchuk 1941).

However, Rydberg's organization of sections ("groups") within Potentilla are considered by most as being highly unworkable and artificial. Indeed, the last North American revision of the genus (Rydberg 1908) included 176 species, which to judge by the few studies done in recent years on groups within the genus (e.g., Clausen, Keck, & Hiesey 1940), is about 2 to 3 times too large.

The descriptors most often used to distinguish species within this genus are:

- Leaf dissection: relative position of leaflets
- Leaf dissection: number of leaflets
- Leaflet dissection
- Leaf pubescence: above/below
- Leaf pubescence: type & density
- Style position
- Style shape
- Inflorescence branching/flower number
- Flower color
- Bractlet shape
- Fruit: pubescence

These might be sufficient to characterize species, but I would probably add descriptors relating to general habit, a few descriptors with quantitative states such as leaf

size, pubescence density, or flower size; and a descriptor involving root form.

These descriptors each have unique problems associated with measurement. The floral characters, for example, should all be measured at the same relative developmental stage, which stage would have to be recognisable on herbarium specimens; perhaps dehiscence of the petals? Flower color, except in a very general way, would not be a good descriptor for herbarium study.

XXXXX

Potentilla in the strict sense is known to have several groups within which apospory and parthenogenesis is widespread and common. For this reason, this genus is usually considered difficult for determining species limitations and affinities. I consider that taxonomic treatment involving herbarium studies alone probably will not make much headway, or will result in more confusion in an already confused nomenclature. The troubles Rydberg got into are worth using as an example.

On the other hand, a complete study of relationships within this genus should probably involve garden-plots of crosses within and between geographically defined groups of species; these techniques would probably not be available in terms of time limits on this Project. However, measurement of the distribution of characters within populations of this genus could be done and would be fruitful, at least to be able to measure the variation in characters; which variation is not usually seen in studying herbarium specimens within apomictic groups.

A rough outline of the proposal:

1. Compile all names applied within Potentilla in the strict sense; compile all descriptions that correspond to these names. These probably would be limited to North America.

2. Select a small group within which herbarium studies and field work can proceed; for reasons already discussed, workable groups do not as yet exist within the genus, except on a level of affinity-groups. I tentatively propose to limit the study to pinnate-leaved species in the Rocky Mountains.

3. Select Descriptors to measure or tabulate for herbarium studies, and those for field studies.

4. Herbarium tabulation of data.

5. Select field sites to study populations.

6. Mathematical analysis of data.

7. Interpretation.

The last two are to follow at a large interval of time, whereas the first five may proceed simultaneously or in close order.

Barry C. Johnston

SEP 09 1975

620 Arapahoe Avenue
Boulder, Colorado 80302
September 8, 1975

Dr. David J. Rogers
1229 University Avenue
Boulder, Colorado 80302

Dear Dr. Rogers:

As you requested, I have given some thought to my future program of work and study, and with some help from our discussion last week, I have made an outline of a proposed program.

Thus far I have taken the following as courses, all at the University of Colorado:

B. S. (Engineering Physics)	1966
Flowering Plant Classification	D. Rogers
Advanced Plant Taxonomy (2 semesters)	A. Löve
Ecological Genetics	Y. Linhart
Genetics	Y. Linhart
Ecology	J. Marr
Mountain Ecosystems	J. Marr
Mathematical Ecology	P. Webber

In addition, I have studied on my own:

1. Variation in the genus Pinus, particularly as regards ecology in subsection Cembroides Engelm., P. edulis Engelm. and P. monophylla Torr. & Frem.
2. Population structure and genetics of polyploid-apomictic complexes, particularly in Potentilla.
3. General ecology and floristics of Colorado and surrounding states, with emphasis on the pinon-juniper zone.

For the last several months, I have been working, on a semi-directed, volunteer basis, with W. Weber in the University of Colorado Herbarium, on some small floristic and taxonomic problems, mostly in Colorado. I have helped update the herbarium's listing of all vascular, bryophyte, and lichen species that grow in Colorado, and will be soon finishing a computer routine to produce punched-card polyclave keys from binary taxonomic data matrices.

As far as further requirements, I would like to suggest a program to include the following courses:

1. Plant physiology and biochemistry.
2. Advanced genetics of flowering plants, with emphasis on crop and food plants.
3. Mathematical theories of plant population structure ("population genetics") with emphasis on
 - a. Crop and food plants
 - b. Polyploidy and apomixis.

Dr. David J. Rogers
September 8, 1975
Page two

4. Advanced history and evolution of cultivated plants; principles and history of plant breeding.

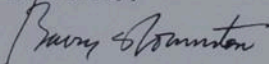
These courses should then be followed by a program re-evaluation and selection of a plant group suitable for study. I have studied polyploid-apomictic European and American species of Potentilla, in which I was concerned with the interrelation of environment, mode of reproduction, and level of ploidy. But Potentilla, however interesting from a taxonomic-genetic point of view, is not of much concern to mankind as a whole. I want to work in an area where my work can be of more use than just a taxonomically interesting problem. The taxonomic approach is the best one, and one that needs more use, but is like more formal mathematics in that, taxonomy is not an end in itself but is useful insofar as it is used to better the lives of people who are not taxonomists.

I would like to make a contribution in the area of application of genetic models to elucidate relationships within and among population units, which may be individuals, "populations", varieties or cultivars, or species). Such work should proceed in order from

1. Collection, correlation, and systematization of data from morphological, biochemical, and cytogenetic sources, and from breeding experiments, to
2. Proposal of possible genetic models to account for the observed information, followed by
3. Invention of suitable experiments to test and refine the models, then
4. Identification and classification of population units, using the models to predict future possibilities for useful work.

I would like to take this opportunity to thank you for your past help and guidance and patience. I hope this outline will help us to work out a program of mutual benefit.

Sincerely,



Barry C. Johnston
620 Arapahoe Avenue
Boulder, Colorado 80302
444-6927

REQUEST FOR CONFIDENTIAL REPORT

The applicant should complete the
1st, 2nd and last lines and give
one form to each recommender.

Barry C. Johnston

IS APPLYING FOR ADMISSION TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF
COLORADO AND HAS LISTED YOU AS A REFERENCE ON HIS APPLICATION FOR GRADUATE WORK IN THE:

Department of Environmental, Population, and Organismic Biology

(DEPARTMENT OR SCHOOL TO BE FILLED IN BY APPLICANT)

BOTH THE APPLICANT AND THE GRADUATE SCHOOL WILL BE GRATEFUL IF YOU WILL FILL IN THIS FORM AND RETURN
IT AT YOUR EARLIEST CONVENIENCE. IT IS REQUIRED BEFORE ACTION CAN BE TAKEN ON HIS/HER APPLICATION.
IF YOU WOULD RATHER WRITE A LETTER IN PLACE OF OR IN ADDITION TO THIS FORM, PLEASE DO SO.

1. HOW WELL DO YOU KNOW THE APPLICANT?

- ☒ VERY WELL (CONTACT WITH THE STUDENT BOTH IN AND OUTSIDE THE CLASSROOM)
☐ BETTER THAN I KNOW THE AVERAGE STUDENT (CONTACTS IN SMALLER CLASSES, SEMINARS, ETC.)
☐ AS WELL AS I KNOW MOST STUDENTS (USUAL CONTACTS IN CLASSES, ETC.)
☐ NOT VERY WELL (CONTACT IN LARGE CLASSES, BUT NOT LARGE ENOUGH TO EXCLUDE SOME CONTACT)
☐ NOT AT ALL (CONTACT IN ☐ CLASS ☐ CLASSES TOO LARGE TO AFFORD OPPORTUNITY TO GET TO KNOW STUDENT)

HAVE YOU SERVED AS HIS/HER

RESEARCH ADVISER ☒
MAJOR ADVISER _____
DEPARTMENT CHAIRMAN _____
OTHER (SPECIFY) _____

2. HOW WOULD YOU RANK THE CANDIDATE IN THE FOLLOWING CHARACTERISTICS IN COMPARISON WITH OTHER STUDENTS YOU HAVE TAUGHT?

	EXCELLENT	GOOD	AVERAGE	BELOW AVERAGE	LOW	UNKNOWN OR NOT OBSERVED
Intellectual ability	☒					
Imagination		☒				
Motivation	☒					
Work habits		☒				
Emotional stability			☒			
Knowledge of literature in his field	☒					
Reading ability in (1) (2) foreign languages						☒

3. IF THIS STUDENT WERE ONE OF YOUR OWN GRADUATE STUDENTS, HOW WOULD YOU RANK HIM?

- ☒ DEFINITELY AS PH.D. MATERIAL ☐ QUESTIONABLE
☐ PROBABLY AS PH.D. MATERIAL ☐ NOT DESIRABLE
☐ DEFINITELY AS TERMINAL M.A. MATERIAL

4. PLEASE ADD ANY COMMENTS WHICH WILL ASSIST US IN EVALUATING THIS APPLICANT FOR GRADUATE STUDY.
(USE OTHER SIDE IF DESIRED.)

Mr. Johnston is more mature than most applicants for graduate school. He has taught in secondary schools, and has considerable insight into pedagogical problems. He was forced by financial difficulties to withdraw from graduate school earlier. He has, however, maintained an active interest in systematic botany and in taxometrics. His knowledge of mathematics is considerable, as well as other allied disciplines. I expect to employ him as a graduate research assistant in my own research activities when he is admitted. I recommend him highly.

RECOMMENDER'S
SIGNATURE:

David J. Rogers

DATE: September 23, 1975

NAME PRINTED
OR TYPED:

David J. Rogers

ADDRESS: Dept. of EPO Biology
University of Colorado
Boulder, Colo. 80302

TITLE:

Professor of Biology

APPLICANT SHOULD INSERT NAME AND ADDRESS BELOW OF CHAIRMAN OF DEPARTMENT TO WHICH HE IS APPLYING FOR GRADUATE WORK.

RECOMMENDER PLEASE RETURN THIS FORM TO:

Chairman, Department of E.P.O. Biology
UNIVERSITY OF COLORADO, BOULDER, COLORADO 80302

Greg M. ARTHUR

loggers

1. "An outline of goals developed for your energy program."

Since the inception of my research related to energy development, I have set up the following four goals for my Dissertation efforts. They are, in ranking order of importance:

1. To develop a suite of ecological and taximetric techniques to accurately and quickly isolate specific grasses capable of revegetating spent oil-shale tailings.
2. To create an amalgamation of botanical, ecological, and environmental information stored within a computerized information retrieval system, in order to facilitate plant selection based upon site-specific criteria.
3. To demonstrate the feasibility of revegetating spent oil-shale using existing biological variability in either native or exotic species of grasses and to accomplish the revegetation with a minimum of human management.
4. To provide for the efficient extraction of the shale resources with a minimum acceptable environmental insult and then return the system to natural (i.e., local) Ecosystemic productivity.

The terms "ecological and taximetric techniques" are herein defined as follows: Ecological techniques constitute a systems approach to the diversity seen in nature; an attempt to predict both pattern and process from a knowledge of the interaction of the component parts. Taximetric techniques consist of a suite of procedures derived from Taxonomic and Information Theory which attempt to provide objective methods for evaluating complex biological data with the assistance of computing machinery.

The two procedures, where coupled, permit rapid extraction of pertinent biological information related to site-specific conditions (such as soil pH, elevation, etc.). I enclose a sample query for the committee's perusal.

During the past six months I have constructed an information base consisting of 314 individual plants selected from 22 species of grasses in 11 genera of the Gramineae. Each individual plant is described by 43 descriptions ranging across the major environmental, botanical, and ecological information required for my study. The control vocabulary for this data bank, illustrating each descriptor, is enclosed.

Additionally, I have begun to expand upon the literature foundation for the thesis work, attempting to locate all articles pertinent to the completion of the four aforementioned dissertation goals. Finally, I have begun germination experiments on several species in the greenhouse, and in short order will begin full scale greenhouse experiments on various mixtures of planting media (spent shale and sludge).

2. "An accounting of what has been accomplished in course work and grades received."

I am registered as a full time Doctoral Candidate and have completed all course work necessary for the Ph.D. I satisfactorily passed my Ph.D. written and oral comprehensive exam in December, 1974. I have earned an "A" in all Ph.D.-related course work and my cumulative graduate grade point average is 3.85.

3. "Research started or completed"

--Started:

- Greenhouse germination studies (selected plant material)
- Expanded literature search

--Completed:

- Information retrieval system data bank containing of 314 individual plants.
- Linkages with major USDA plant introduction centers for acquisition of seed material.

4. "Publications, if any."

None.

5. "New objectives to be attained, courses to be taken, and research to be completed if traineeship is reviewed."

A single, potential new objective, growing directly out of the current work may be the elucidation of parental lines to develop superior hybrids for re-vegetation of any disturbed habitat. I do not see this as germane to the current oil-shale work, but is certainly a possible post-doctoral research avenue.

I have yet to complete:

- Greenhouse growth studies
- Field testing of results
- Writing of the thesis.

I hope this information will permit the review committee to assess my capabilities as regards our nation's energy R & D programs. Should the committee require any additional information, please feel free to contact me at any time.

DATE: 01/26/76

ENTER NEXT COMMAND

? READ DATA BANK PHDHOPE*

DATA BANK STORED ON FILE PHDHOPE 11/17/75

ENTER NEXT COMMAND

? HOW MANY HAVE SOIL PH. FROM 7.5 TO 8.0*

NO. OF ITEMS IN QUERY RESPONSE = 85
NO. OF ITEMS IN THE DATA BANK = 316
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = 26.90

DESCRIPTORS

ENTER NEXT COMMAND

? HOW MANY HAVE ELEVATION, 8500 AND ROOT HABIT, BUNCH*

NO. OF ITEMS IN QUERY RESPONSE = 2
NO. OF ITEMS IN THE DATA BANK = 316
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = .63

? PRINT: (ACCESSION NUMBER, GENUS, SPECIES, COMMON NAME, SOIL PH,
? ORIGIN, DESIRABILITY) FOR SAME WITH RESULT*

NO. OF ITEMS IN QUERY RESPONSE = 2
NO. OF ITEMS IN THE DATA BANK = 316
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = .63

QUERY RESPONSE INFORMATION

229607	AGROPYRON	CRISTATUM	FAIRWAY WHEATGRASS	5.5	IRN	HIGH
229615	AGROPYRON	INTERMEDIUM	INTERMEDIATE WHEATGRASS	5.5	IRN	UNKNOWN

? HOW MANY HAVE AGGRESSIVENESS, STRONG AND ROOT HABIT, 500*

NO. OF ITEMS IN QUERY RESPONSE = 2
NO. OF ITEMS IN THE DATA BANK = 316
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = 2.53

ENTER NEXT COMMAND

? PRINT: (ACCESSION LN. *DEL*

PRINT: (ACCESSION NUMBER, GENUS, SPECIES, ANNUAL PRECIPITATION,
? ORIGIN, PHYTOGEOGRAPHIC CLASS) FOR SAME WITH RESULT*

NO. OF ITEMS IN QUERY RESPONSE = 8
NO. OF ITEMS IN THE DATA BANK = 316
PERCENTAGE OF RESPONSE/TOTAL DATA BANK = 2.53

TOTAL RUN TIME IN SECONDS
CENTRAL PROCESSOR=

204383	AGROPYRON	ELONGATUM	5 DM	TURK	EXOTIC
206387	AGROPYRON	INTERMEDIUM	2 DM	TURK	EXOTIC
210891	AGROPYRON	CRISTATUM	9 DM	AFG	NATURALIZED IN COLORADO
229675	AGROPYRON	INTERMEDIUM	7 DM	IRN	EXOTIC
234750	PESTUCA	OVINA	15 DM	SPN	NATIVE TO COLORADO
235705	AGROPYRON	TRACHYCAULUM	12 DM	CAN	NATIVE TO COLORADO
235709	AGROPYRON	TRACHYCAULUM	7 DM	CAN	NATIVE TO COLORADO
235715	AGROPYRON	TRACHYCAULUM	5 DM	CAN	NATIVE TO COLORADO

Very
Fast!

Apr. 2, 1980

Chris:

You have no more responsibility for the Vitis study because your own research and thesis must take priority. Your work with that in the present situation is in jeopardy, because you have not done what I have asked you to do with it.

Whatever else, you must communicate about the Mertensia
~~Mertensia~~ study.

DJR

PRELIMINARY EXAMINATION for
CHRIS MCCARTHY
3/15,16/79

Instructions:

You have two half days (three hours each) to answer the following questions. In the two half days, you must have answered at least one question from each of the four areas chosen, namely: General Biology; Anatomy, Morphology, and Physiology; Genetics and Evolution; and Systematics and Taxonomy.

You may elect to answer more than one question from each of the areas.

Please number each question, and write the question down in your answer sheet before proceeding. Good organization, spelling and clarity are important considerations.

GENERAL BIOLOGY

(From Dr. Bock)

1. Compare and contrast meiosis and mitosis in an angiosperm cell.

2. Delimit the organelles of a typical photosynthetic plant cell.

3. What reasoning was used to establish five kingdoms of organisms.

(From Dr. Bye)

4. The concepts used in classifying the major kingdoms of organisms have undergone considerable change in recent years. Discuss the biological bases for the different systems of kingdom classification and the major ecological roles of the kingdoms in the biosphere.

(From D. Rogers)

5. Contrast the two categories, "higher plants" and "higher animals" on any two of the following disciplinary lines: Morphological (including anatomical), ecological, physiological, genetic, or taxonomic. Give examples of the characteristics you discuss.

PLANT ANATOMY, MORPHOLOGY, PHYSIOLOGY

(From Dr. Bock)

6. Contrast primary growth in monocots versus dicots.

7. Describe the structure and function of phloem in angiosperms. Give all types, organization of tissue and discussion of the transport system and substances transported.

(From Dr. Bye)

8. What are some of the trends of specialization (e.g. morphological, anatomical, reproductive, etc.) found within and among major groups of vascular plants.

(From D. Rogers)

9. Give a diagram illustrating the major flow of activities, inputs and outputs, for photosynthesis, and discuss the values or disadvantages for the C_3 versus C_4 pathways.

GENETICS AND EVOLUTION

(From Dr. Bye)

10. Discuss co-evolutionary responses and illustrate with some examples ((explaining the ecological and evolutionary details)).

(From Dr. Bock)

11. Why is the origin of the angiosperms such an abominable mystery?

(From D. Rogers)

12. Discuss the various types of mutations--what they are, how they may arise, and the results of these.

Questions for Chris McCarthy, Master's prelim.

SYSTEMATICS AND TAXONOMY

(From Dr. Bock)

13. Discuss the contributions of modern numerical taxonomy to the plant biosystematics.
14. What would have been the greater tragedy to modern botany--if Charles Darwin or Carolus Linnaeus had died in infancy?

(From Dr. Bye)

15. What roles does hybridization play in taxonomic studies of plants?

(From D. Rogers)

16. Give a statement of the major principle in taxonomy, and what the implications of this principle are.

I. Style terminal.

a. Style twice forked. Ovary not lobed.

b. Style simple and once-forked, or styles 2 and distinct.

1. Ovary not lobed.

2. Ovary mostly 4-lobed. Stigmas subtended mostly by a hairy ring.

II. Style arising between the nearly separated ovaries.
Fruit separating into 1-seeded nutlets.

I. Cordioideae.

II. Ehretioideae.

III. Heliotropioideae.

IV. Boraginoideae.

1. Lithospermeae

2. Anchuseae

3. Eritrichieae

4. Cynoglossaeae

istics has been compiled from Baillon, Benthom and Hooker, Engler and Prantl, and De Candolle.

Subfamily I. Cordioideae: ovary undivided; style terminal, two parted; stigma clavate or capitate; cotyledons plicate or corrugated; fruit fleshy, drupeaceous; endosperm lacking. Habit: woody.

Subfamily II. Ehretioideae: ovary undivided to four lobed; style terminal to lateral, two parted or simple; stigma capitate; cotyledons plane; fruit semi-fleshy or semi-dry; endosperm copious and fleshy to nearly lacking. Habit: trees, shrubs, to low herbs.

Subfamily III. Heliotropioideae: similar to the last but style simple; endosperm lacking. Separated on the distinct stigmatic modification.

Subfamily IV. Boraginoideae: ovary distinctly divided into four nutlets; style basal, entire to 2-cleft; stigma truncate to capitate; cotyledons plane; fruit dry; ovules ascending or erect; endosperm lacking. Habit: chiefly herbs.

1951]

Britton: Cytogenetic Studies on the Boraginaceae

<i>Mertensia ciliata</i> (James) C. Don.	Andrews, Boulder, Colo.	24	Britton
<i>Mertensia ciliata</i> (platensis coll.)	Andrews, Boulder, Col.	48	Britton
<i>Mertensia elongata</i> Benth. ex C. B. Clarke	University Botanic Garden, St. Andrews, Scotland	24	Britton
<i>Mertensia maritima</i> (L.) S. F. Gray		24	Löve and Löve 1948
<i>Mertensia sibirica</i> C. Don.		24	Strey 1931
<i>Mertensia virginica</i> Link.	Clarke Co., Va.	24	Britton

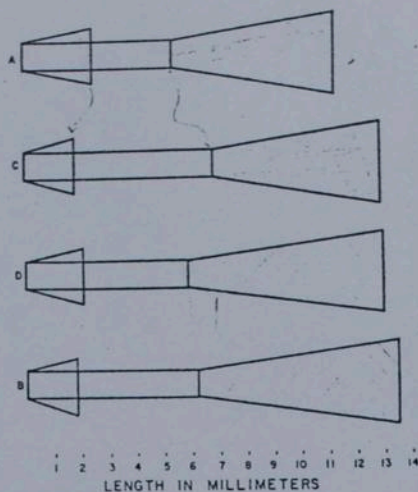


FIG. 1. Idiograms showing average lengths in millimeters of calyx, corolla tube, and corolla limb in clones A, B, C, and D of *Mertensia ciliata*.

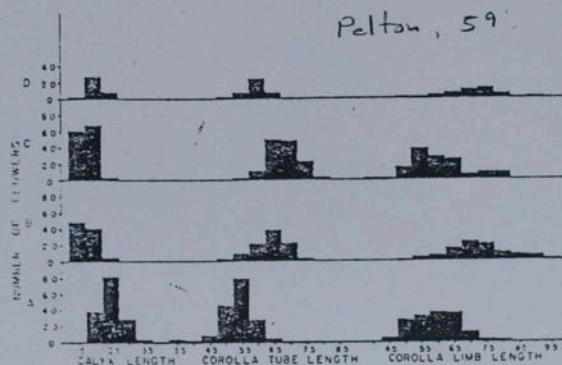


FIG. 2. Histograms showing distribution of individual measurements in millimeters of length of calyx, corolla tube, and corolla limb in clones A, B, C, and D of *Mertensia ciliata*.

Characters:

1. Leaf Length (of mid-cauline leaf)

States: _____ cm. from 2 cm to 7 cm.

2. Leaf Shape (of mid-cauline leaf)

States: 1. oval
2. narrow ovate
3. lanceolate
4. narrow-lanceolate

3. Plant Height (of tallest shoot)

States: 1. tall (26-34 cm)
2. medium (12-25)
3. short (8-11)

4. Vesture of Upper Leaf Surface

States: 1. glabrous
2. villous
3. strigose
4. sericeous
5. warty
6. pustulate

5. Vesture of Lower Leaf Surface

States: 1. glabrous
2. villous
3. sericeous
4. strigose

6. Pubescence of Leaf Edge Type

States: 1. appressed long
2. appressed short
3. villous
4. spiky
5. warty

7. Vesture of Stem

- States: 1. glabrous
2. villous
3. strigose
-

8. Inflorescence Density

- States: 1. tightly clumped at anthesis
2. widely spreading at anthesis
3. intermediate
-

9. Pedicel Pubescence

- States: 1. none
2. villous
3. sericeous
4. strigose
5. warty
6. pustulate
7. grouped pustulate
8. spiky
-

10. Calyx Division

- States: 1. divided to base, or nearly
2. cup remaining, less than 1/2 calyx
3. cup remaining, approx. 1/2 calyx
4. cup remaining, greater than 1/2 calyx
-

11. Calyx Lobe Shape

- States: 1. broad wedge
2. moderate triangular
3. straight-edged
4. elongate
-

12. Calyx Lobe Pubescence

- States: 1. none
2. villous
3. sericeous
4. strigose
5. spiky
-

13. Total Corolla Length

States: ____ mm. (from 7mm to 16 mm)

14. Length of Limb of Corolla

States: ____ mm. (from 3 mm to 7 mm)

15. Length of Filaments

- States: 1. extremely short (indistinguishable)
2. elongate (1.6-2.4 mm)
3. short (1.0--1.5 mm)
4. extremely elongate (2.5--3.0 mm)
-

16. Anther Length

- States: 1. large (2.0 mm)
2. medium (1.5 mm)
3. small (1.2 mm)
-

18. Pubescence of Fornices

- States: 1. none
2. granular
3. sparse villous
4. dense villous
-

17. Fornices:

- States: 1. prominent
2. inconspicuous
-

19. Density of Hairs Inside Corolla

- States: 1. dense
2. intermediate
3. sparse, scattered
-

527 4213220331 41C612121
 994 4113121341 21C612121
 528 4213121411 21A622121
 519 3113121341 21B422221

426 4213322331 229422121
 992 3223121341 41B622121
 435 7211121212 21D422120

Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
5	2 _u	1 _o	2 _i	2 _s	1 _z	2 _z	1 _o	2 _s	1 _z	2 _i	1 _o	2 _i	2 _o	2 _o	2 _i	2 _z	2 _i	2 _z	2 _i
		1 _i			1 _i		1 _i		1 _o		1 _z								
8	3 _u	2 _o	4 _i	4 _z	3 _i	4 _z	1 _o	3 _z	2 _u	4 _i	1 _o	4 _i	2 _o	3 _o	2 _i	4 _z	3 _i	4 _z	4 _i
	1 _z	2 _i			1 _z		3 _i	1 _o	1 _z		3 _o		3 _i	1 _o	2 _z		1 _z		
A									1 _i				1 _z	1 _o					
13	4 _u	5 _z	6 _i	6 _z	5 _i	6 _z	5 _i	5 _z	3 _u	6 _i	5 _z	6 _i	2 _o	4 _o	5 _z	7 _z	6 _i	7 _z	6 _i
	2 _z	2 _i	1 _z	1 _i	1 _z		1 _z	1 _z	2 _i	1 _z	2 _u	1 _z	2 _o	3 _u	2 _i		1 _z		1 _o
	1 _z				1 _z		1 _o	1 _u	2 _z				1 _u						
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Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
3	2 ₃	2 ₁	2 ₂	2 ₃	2 ₁	2 ₂	2 ₁	2 ₃	1 ₁	2 ₃	1 ₁	2 ₃	2 ₁	1 ₁	2 ₅	2 ₂	1 ₁	1 ₁	1 ₁	1 ₁
								1 ₄			1 ₁		2 ₁	1 ₁			1 ₂	1 ₁	1 ₁	1 ₁
7	3 ₃	2 ₁	3 ₂	3 ₃	3 ₁	3 ₂	3 ₁	1 ₁	2 ₃	2 ₁	3 ₃	3 ₁	2 ₁	3 ₅	3 ₂	2 ₁	2 ₁	1 ₁	1 ₁	1 ₁
		1 ₁						1 ₁	1 ₁	1 ₁	3 ₁		1 ₁		3 ₂	2 ₁	1 ₂	1 ₂	1 ₂	2 ₁
								1 ₃											1 ₁	
11	5 ₃	3 ₁	4 ₂	5 ₃	5 ₁	5 ₂	5 ₁	3 ₃	3 ₂	4 ₁	5 ₂	5 ₁	4 ₃	3 ₅	4 ₂	4 ₂	3 ₁	2 ₂	3 ₁	
		1 ₂	1 ₁					1 ₁	2 ₄	1 ₁			1 ₁	1 ₄	1 ₄	1 ₁	1 ₂	1 ₁	2 ₁	
		1 ₃						1 ₄						1 ₇			1 ₁	1 ₃		
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992 3223121341 41B622121
 518 3223121341 21B522121
 519 3113121341 21B422221
 517 3223121341 21C532122

526 4323121241 41D642131
 995 3123121131 21B521000
 994 4113121341 21C612121
 525 3123121430 21A522111
 527 4213220331 41C612121
 528 4213121411 21A622121

435 7211121212 21D422120
 529 3323121331 21B742130

Level

Gen

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

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532 5303121341 41C641133

520 0002232421 229422120
→ 992 3223121341 41B622120
527 4213220331 41C612121
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10	1 ₄ 1 ₅	2 ₃	1 ₂ 1 ₀	2 ₃	2 ₁	2 ₂	2 ₁	1 ₂ 1 ₃	2 ₄	2 ₁	2 ₄	2 ₁	1 ₀ 1 _c	2 ₆	2 ₄	1 ₂ 1 ₁	2 ₁	2 ₃	1 ₁ 1 ₃
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431	4222232431	22A422213
520	0002232421	229422120
427	2232232121	429342121
*426	4213322331	229422121
430	3414212401	22A522121
523	4424212231	229432121
466	3323212441	23B422121
533	4223121331	219422210
527	4213220331	41C612121

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
9	1 ₄	2 ₂	1 ₂	3 ₂	3 ₂	3 ₂	3 ₂	2 ₄	2 ₂	3 ₁	2 ₂	3 ₂	2 ₉	2 ₄	2 ₂	3 ₂	2 ₁	2 ₂	1 ₃
	1 ₂	1 ₀	1 ₃					1 ₁	1 ₃		1 ₄		1 ₈	1 ₃	1 ₄		1 ₂	1 ₁	1 ₁
	2 ₀		1 ₀																1 ₀
	*			*	*	*	*	*	*	*		*							
13	3 ₄	3 ₂	3 ₂	3 ₂	6 ₂	3 ₁	7 ₂	4 ₄	3 ₂	6 ₁	6 ₂	6 ₂	4 ₉	5 ₄	5 ₂	7 ₂	6 ₁	6 ₂	5 ₁
	2 ₂	2 ₄	2 ₁	2 ₃	1 ₃	3 ₃		1 ₃	2 ₂		1 ₄	1 ₃	2 ₈	1 ₃	1 ₃		1 ₂	1 ₁	1 ₃
	1 ₂	1 ₃	1 ₃	2 ₄		1 ₂		1 ₂	1 ₄				1 ₈	1 ₅	1 ₄				1 ₀
	1 ₀	1 ₀	1 ₀					1 ₁	1 ₀										

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THESIS PROPOSAL

Christine McCarthy

The genus Mertensia has long been recognized as presenting a particularly difficult taxonomic problem. L.O. Williams, in his 1937 monograph of the Mertensia, stated "...the genus is one which does not lend itself to a straightforward enumeration of characters by which entities may be differentiated." A number of closely related species in the genus are found to bear bimorphic, if not trimorphic, flowers, rendering those floral characters involved somewhat less than definitive. Vegetative characters, varying with respect to leaf shape and indumentum type and position, likewise fail to provide a clear basis for discrimination of taxa, and individuals representing three or four recognized varieties, as presently defined by means of primarily vegetative characters, may often be found on the same herbarium sheet.

Before understanding the taxonomic status of a set of individuals bearing a given constellation of character states, it is necessary to understand explicitly the ease with which those characters may vary within a population, and the nature of character to character correlations, as well as the correlations of character states with environmental, geographic, and temporal parameters.

It is the purpose of the present work to address this problem. Variation in the morphological characters in the genus Mertensia will be examined, both through study of herbarium specimens and through extensive field study. Chemotaxonomic data will be gathered, in an attempt to provide a meaningful check on the variable morphological features. All data obtained will be analyzed

with the aid of two computer programs, "Charanal" and "Graph", to determine first, the "information content" of each character, and second, the relative similarities within and between groups, the members of which may display a complex array of overlapping character states.

The present study will focus on the Mertensia bakeri-Mertensia viridis complex, which Williams (1937) considers to be "a most complex assemblage, the entities of which are not always clear cut and easily defined." It is expected that progress made here through extensive and detailed study may well provide valuable insight into the problems of the genus as a whole.

METHODS AND MATERIALS

1. Herbarium Study: Specimens will be obtained from the following herbaria, and studied with respect to their morphological characters, in particular: facies, height, leaf shape and size, indumentum type and position, calyx shape, corolla shape (tube:limb ratio), corolla tube vesture, fornice type and vesture, stamen shape, filament shape, style length, and the relative position of the floral parts with respect to one another.

Herbaria: University of Colorado Herbarium
Rocky Mountain Herbarium
U.S. Forest Service Herbarium, Fort Collins
Missouri Botanic Garden Herbarium
New York Botanic Garden Herbarium
Specimens from other herbaria, as yet uncontacted, will also be employed in the study.

2. Field Study: a) Mass collections will be made throughout the range of the species under study, at the approximate estimated date of flowering. Particular emphasis will be given to populations occurring at the type localities, and to populations found through the Herbarium Study to present anomolous features.

b) Certain populations will be studied extensively throughout the summer of 1978 to determine the variability, particularly in floral characters, achieved in single populations over an entire growing season.

3. Chemotaxonomic Study: Sufficient material will be gathered during the Field Study to allow chemotaxonomic analysis. It is anticipated that two techniques - paper chromatography and gel electrophoresis - will be employed, to analyze flavanoids and isoenzymes, respectively.
4. Computer Aided Data Analysis: The use of two programs is presently anticipated. These are: 1) Charanal, a program based on information theory, providing a numerical assessment of relative value, or 'worth', of each character studied; and, 2) Graph, a program determining a single similarity value for every entity studied with respect to every other entity, and providing a graphical portrayal of all relationships thus defined. Further computer aided analytical techniques are currently being investigated, and will be employed as appropriate.

Funding: It is anticipated that funding will be required primarily to offset travel expenses incurred in the collection of specimens, both in the field and from the various herbaria. No funding has been acquired to date; however, potential sources include Sigma Xi, the American Philosophical Society, and the American Museum of Natural History. Further sources are presently being investigated through the University Office of Contracts and Grants.

Conclusion: It is hoped, through this study, to determine the optimal basis for classification within the genus Mertensia. Results anticipated will be:

1) an understanding of the variability of morphological characters with respect to time, location, and environment; 2) a correlation of morphological characters with chemotaxonomic characters; and 3) an improvement in the understanding of the relationships within a select group of the genus Mertensia, leading if necessary to a restructuring of the taxonomic relationships within that group.