

CONSTRUCTION AND USE OF TABULAR KEYS

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Abstract: Tabular keys differ from dichotomous keys in that the statements of characters and variants are separated from the names of the taxa to be identified. This is done by applying cognitive code symbols to the character variants, and recording the distribution of the variants for each of the taxa in tabular form.

The use of Key Groups (KGG), in which carefully selected characters are presented in groups of ca. 5, makes it possible to handle taxa of any size with relative ease. Tabular keys are open-ended, so that expansion of the key is accomplished by adding new groups of taxa and groups of differentiating characters at the open ends, eliminating the need for complete revisions of the key. Selection and coding of characters, preparation of the tables and the data card file are described.

Tabular keys are valuable tools in revisional studies, in the organization and location of unidentified material in large collections, in information storage and retrieval, and in the communication of information.

INTRODUCTION

Throughout most of the history of systematic biology, the standard tool used in identification of organisms has been the dichotomous key. The user of a dichotomous key compares a particular character with pairs of statements in the key, and selects that member of the pair which most nearly agrees with the specimen at hand. This process leads eventually to a terminal dichotomy containing the name of a taxon which may or may not be that of the specimen. When the task of identification is completed, one is left with a name, hopefully the correct one, and essentially nothing else. There is almost no way that the information in a dichotomous key can be utilized except in the identification process. When numerous new taxa are added to the group, the dichotomous key must be laboriously recast, often in its entirety.

For many years now I have employed a type of key which has distinct advantages over dichotomous keys (Newell 1951, 1953, 1957; Newell & Ryckman 1966). Because these have been published in papers dealing exclusively with Acari, they have probably missed the attention of many workers who would find this type of key useful in their own research or teaching. Accordingly, I am presenting here a summary of the principles involved, and specific details on the mechanics of constructing tabular keys, in the hope that others may find them useful. These have been termed *tabular keys*, because the information is presented in tabular form. Tabular keys are not only useful in identification, but also in information storage and retrieval. Since all of the major characteristics are given for each taxon, a quick scan of the table will show not only in what ways a given taxon differs from all other taxa in the group, but also in what

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ways they are similar. This type of information is irretrievably buried in a dichotomous key.

From a functional standpoint, the major advantage of a tabular key is that it can be made open-ended. In a tabular key to a large taxon, there may be numerous open ends, but expansion of the key is accomplished by simply adding new taxa at these open ends, and where necessary, new groups of statements of characters to separate these taxa. If the selection of characters and statements of characters were perfect, it would never be necessary to recast a tabular key regardless of how many new taxa were incorporated into it. This degree of perfection has never been achieved, at least by the writer, but certainly the task of revising a tabular key is minuscule compared with that of revising a dichotomous key of comparable size.

CODING OF CHARACTERS

Dichotomous keys and tabular keys are similar in that both include (a) statements of characters and the observed variants (or states) of these characters, and (b) taxa to be identified. In what ways, then, do they differ? The principal difference lies in the fact that, in dichotomous keys, the statements of characters and the taxa to be identified are inextricably intermingled, while in tabular keys the statements of characters and variants, and the taxa to be identified, are kept separate. This separation requires an additional step in the preparation of tabular keys, namely the *coding of characters*.

In the earliest tabular keys published by the writer, the code symbols used were abstract. Each character variant (or state) was indicated by an a, b, or c ... , depending upon the number of variants observed (e.g., Newell 1951, 1953). In recent years I have modified this by using *cognitive character codes*, in which the symbols give some direct indication of the variant in question, e.g.:

1. Tritosternum, presence or absence.
t=*Tritosternum* present.
a=*Tritosternum absent*.
2. Which segment of leg II is longer, *patella* (p) or *femur* (f)?
3. Presence or absence of ambulacrum on tarsus I.
a=*Ambulacrum* I present.
o=*Ambulacrum* I *absent*, etc.

Cognitive codes have the distinct advantage that they are learned rather easily after a few runs through the key, so that it is scarcely necessary to more than glance at the statement of characters to know which code to apply. With more abstract codes (a, b, c...; 1, 0, etc.) this would be far more difficult and much more likely to lead to error.

For workers whose native language is not English, the code symbols can be simply transliterated to ones which are more meaningful. This is not as great a problem as it may seem at first, since so many of the terms, and their cognitive letter symbols are derived from Greek or Latin. Or, in certain cases the codes will be the almost universally used Arabic numerals, as in the case of setal counts, (e.g.: Number of setae on trochanter I-IV: 1-0-0-0, or 1-1-1-1), ratios (length/width=1.35, 1.48, 1.79, 2.09 etc.), positions of particular setae or structures (solenidion₁ at .35, .48, .63, etc.).

With experience, when cognitive code symbols are used, it becomes a relatively easy matter to write the formula for a particular Key Group (see following section) for a given specimen almost at a glance. It is unnecessary to double-check carefully in each case to ascertain that the correct symbol has been utilized.

GROUP TABULAR KEYS

When the number of subtaxa to be keyed is relatively small, it is possible to show all characters for all subtaxa within a single table (Newell 1951, 1953, 1957, 1966, etc.). But when the number of subtaxa is very large, this becomes impractical. This problem is solved by the introduction of *Key Groups* (Newell 1959). While the principle of Key Groups was first utilized by the writer in a dichotomous key, the principle is even more easily applicable to tabular keys. In fact, the dichotomous key to the aquatic mites (Newell 1959) was constructed from a detailed tabular summary of the distribution of character variants. In a *Group Tabular Key*, the character variants are presented in small sets of several characters. Ideally, the characters for the initial Key Group (KG 1) and the second and even third KGG should be carefully selected to hold the subtaxa together in reasonably natural groupings, so far as practicable. In the ultimate levels of the key, the emphasis will be on dispersion.

Selection of Characters for KG 1. - As pointed out above, the emphasis in selection of characters for KG 1 should be on maintaining natural groupings of the subtaxa, insofar as possible, provided this can be done and still produce a workable key. Computer studies will be helpful, but not indispensable, in selecting the characters and variants to be used. Broad general experience in a group will usually achieve the same result. The characters which will best do this can often be found in the initial couplets of good dichotomous keys, but this is by no means always true.

Most structural characteristics used in systematic work fall into one of two fairly discrete categories: (a) discontinuously and (b) continuously varying characters. Discontinuously varying characters include presence or absence of a particular structure, differences in position or form of a structure not subject to overlapping variation, absolute differences in setal numbers, etc. This type of character is preferable in the introductory levels of group tabular keys. Continuously varying characters include direct measurements, ratios, decimal notations of positions of setae, setal counts showing overlapping variation, etc. This type of character should be reserved for use in later KGG.

Characters which are known or which appear to have arisen a number of times within the evolution of the taxon should be avoided in KG 1. For example, in the genus *Copidognathus* (Acari: Halacaridae), one of the most easily interpreted characters is the number of dorsal setae on tarsi III and IV. These are found in 3 easily differentiated states (3-3, 4-3, or 4-4). But a survey of the distribution of these variants suggests that they have arisen independently in several species groups. In fact, recent information (Newell 1969) suggests that this character is subject to ecological variation within a single species. Such labile characters should be reserved for terminal levels of a group tabular key.

While there is no fixed number of characters that can be utilized effectively in KG 1, I have found through experience that more than 5 characters usually leads to an undesir-

able degree of dispersion of natural groupings of subtaxa in KG 1. Experience should be the guide, however, and anywhere from 3 to 7 characters may be used, depending on the taxon.

In dichotomous keys the use of more than two variants at a time for a single character often leads to confusion, and many workers scrupulously avoid trichotomies. Thus

Rhombognathus - KG 1. (Females or males) 1966 (1969 Revision)

1. Normal number of setae on bf II (2, 3, 4, 5). Closely linked with characters 2 and 3. No known sexual dimorphism.
2. Number of pairs of perigenital setae in female (6, 5, 4, 3, 2, 1).
3. Number of pairs of setae in PD (1 or 2). In the few species with fused dorsal plates, the number of pairs in that portion of the composite plate which would normally be subtended by PD.

Do not mistake the long internal apodeme of PD for a seta. Virtually all char. 2 - 5 and char 6 - 1 species have 1 pair of setae in PD, but these are exceptions (e.g. R. plumifer?). No known sexual dimorphism.

4. Form of pecten and accessory process of lateral claws, as seen in ventral view. No known sexual dimorphism.

e = Endoplanate, accessory process broad, rake-like, with 12 or more teeth (Fig. 4e).

p = Palmate, accessory process narrow, but with 6 to 30 minute teeth along margin, the teeth sometimes visible only under oil (Fig. 4p).

c = Ctenoid, with a long comb-like pecten running along the medial margin of the shaft of the claw as in most Halacarinae; teeth coarse to extremely fine (Fig. 4c).

u = Unidentate, accessory process a single delicate tooth, often visible only under oil immersion.

s = Smooth, even under oil immersion.

5. Number of discrete ventral plates (1, 2, 4).

1 = One, AE, PE and GA all fused, not separated by bands of striated membranous cuticle. Most go here.

2 = Two, right and left PE fused with GA to form one plate, separated from AE by a complete transverse band of membranous cuticle (Fig. 5,2).

4 = Four, AE, GA and right and left PE all separated by membranous cuticle.

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6. (Male only) Number of basilar setae on each side of genital foramen (1, 2, 3, 4, c) In R. [redacted] n. sp. and R. gressitti Newell 1964, these are more or less continuous with the other perigenital setae, and not set off as a discrete group (Fig. 6,2, 6c).

Fig. 1. Facsimile reproduction of the statement of characters and character variants for KG 1 of the tabular key to the genus *Rhombognathus* Trouessart (Acari, Halacaridae).

in a dichotomous key to the genus *Rhombognathus* (Acari: Halacaridae), the classical way to present the character of the number of setae on basifemur II would be:

- 1. With 2 setae on bf II x
- With 3 or more setae here..... y

If the user of the key is curious about which species have 3 and which have more than 3, he must search through subsequent dichotomies to learn this, and as often happens, that particular character may not be expanded upon in subsequent dichotomies. Even if it is, it will probably not be given for all species. In a tabular key, polychotomies

Rhombognathus - KG 1

1966 (1969 Revision)

2	5	1	ε	1	1	<u>KG 100.</u> (<u>magnirostris</u> , etc.)
2	5?	1	ε	1?	1	<u>praegracilis</u> Viets 1940/orig. descr.
?	?	1	ε	1	?	<u>Sphaerorhynchus</u> Police 1909/od
2	5	1	p	1	1	<u>notops</u> (Gosse) 1855/redescr. Newell 1956
2?	?	1	p	1	1	<u>parvulus</u> Viets 1939/od
2	5	2	ε	1	1	n.sp.
2	1	2	ε	1	1921	<u>plumifer</u> Trt. 1889/type + sl. 5316-30.04.
3	5	2	s	1	2	n.sp.
3	4	2	p	1	2	<u>KG 400.</u>
3	4	1	c	4	2	<u>peltatus</u> Viets 1939/sl. # 5017-23 + od
3	3	2	p	1	2	<u>KG 700.</u>
3	3	2	u	1	2	n.sp.
3	3	1	u	1	?	<u>lionyx</u> Trt. 1900/Newell & Andre redescr.
?	?	?	ε	1	?	<u>apsteini</u> Lohm. 1907/od
?	?	?	?	1 or 2	2	<u>terminalis</u> Sokolov 1952/od
4652	6252?	s	4	3, 5, 2		<u>gressitti</u> Newell 1967/od

Fig. 2. Facsimile reproduction of the table for KG 1, as it appears in the looseleaf notebook, showing distribution of the variants in the genus *Rhombognathus*. Several new species have been deleted. *R. apsteini* and *R. terminalis* are inadequately described forms whose placement is provisional.

are no problem, and all of the clearly definable variants of one character are stated at the same place. The above character would be stated as:

1. Number of setae on bf II (2, 3, 4, 5).

To begin with, I write each character and its several variants on individual index cards or sheets of paper. When the several characters for KG 1 have been selected, they are tested against all appropriate subtaxa. Some of the characters may be found impractical because of excessive variability, ambiguities in definition, or difficulties in seeing the character. These can be replaced with better characters, if available, and a final list of characters for KG 1 is prepared. This can be further refined on the basis of subsequent experience, but if the initial selection is done well, it will never be necessary to totally replace this list of characters.

Fig. 1 is a reproduction of the statement of characters for KG 1 of my tabular key to the genus *Rhombognathus* Trouessart (the illustrations have been omitted to conserve space).

Data cards for use with tabular keys. - Fig. 3 is a facsimile of the 4"x6" data card used in the construction of tabular keys. For routine determinations of known species, it is not essential to prepare a data card, but wherever it is felt that a valuable new record or a potential new taxon is involved, a data card is highly desirable. They are indispensable in the construction of tabular keys.

The space at the top left of the card is reserved for the name of the taxon, if known, and the specimen number. Other data are optional. More than one specimen may be

NAME: *Rhs mag* Trt.

REF: orig. desc. + restudy of type material / Mswell & André 1959

LOC: "Mediterranéε"

1	2	5	1	ε	1	? (a)			
100	a	1	7.7.3.3	5.5.3.3	0.0.0.0				
175	2.1.1.2	5.5.5.5	?		432x	? (a)		Med (b)	

(a) No ♂ in type series. (b) Not identified further.

Fig. 3. Reproduction of a data card showing data derived from a restudy of the type specimen of *Rhombognathus magnirostris* Trouessart.

accommodated on a single card, where it is certain that these represent the same taxon. The rest of the card is reserved for the formulae of various KGG which must be gone through to arrive at a determination, and for notes. The species selected as an example keys out to KG 100 at the second level and eventually to *R. magnirostris* Trouessart 1889 in the third level (KG 175). The statements of characters for KGG 100 and 175 are not included here.

Construction of the table for KG 1.—Data cards should be prepared for as many of the subtaxa as possible within reason. The greater the number available at the outset, the better the representation of variability within KG 1 and the later sections of the key, and the less the problem of subsequent revisions. In very large collections involving, say, thousands of specimens, it may be necessary and adequate to sample the collection in a systematic manner, and to defer the completion of the identifications until after the key has been constructed. If the sampling is done well, and if the collection is reasonably representative of the total variability within the taxon, subsequent modifications of the key will be minimal. Wherever possible, data cards should also be prepared for named and adequately described taxa in the literature.

When all cards are prepared for KG 1, they are arranged according to some consistent scheme. Unless taxonomic circumstances dictate otherwise, the cards can be arranged alphabetically for character 1, e. g. 1a-1c-1e. Then all cards with character 1 coded *a* are arranged according to character 2, the same is repeated for cards coded *c*, and finally for *e* cards. This is repeated until all cards for KG 1 have been arranged for all characters. Some cards may not have complete formulae, for one reason or another, and these are simply left at the most logical place in the array of cards. Where the cognitive symbols are numerals, these are generally arranged in the order of increasing value, unless it is seen that this scatters known or presumed natural groupings of subtaxa to widely separated parts of the key. In this case it is preferable to follow an arrangement of the symbols which will best preserve the known or presumed relationships. The sorting described above can be done on a desk, and when completed, there will be a number of individual piles of cards. Some piles may contain a single card, while others will contain many. The formula for each pile is then entered in a table which is prepared on 1/5" cross-ruled notebook paper. If a particular pile has only one card, the formula, followed by the name of the taxon, or the specimen number or any other identifying data can simply be left in KG 1. If the pile contains more than one card, and these represent more than one nameable taxon, then a second-level KG number is selected for that pile of cards. For large taxa I prefer to distribute the KGG from 1-999, to minimize later revisions of the KG numbers. Since this is normally adequate to accommodate many thousands of subtaxa, it is seldom necessary to rewrite KG numbers, unless a mistake is made in their initial distribution. If this occurs, the changes are made only on paper, and can be accomplished easily. Or, one could go to a decimal system, say KG 599.500, etc., but this becomes unwieldy, and should be avoided.

Fig. 2 is a facsimile of the table for KG 1 of the genus *Rhombognathus*, showing the distribution of character variants.

Assignment of second-level KG numbers within KG 1.—Inspection of the individual piles of cards following sorting of KG 1 will usually show how subsequent KG numbers should be distributed. Greatest room for expansion should be left for those parts of

the key represented by the largest piles. If one of the piles contains, e. g., one-half of the cards, then skip 200 or 300 numbers before assigning the next number. Thus, the array of KG numbers listed in the table for KG 1 might be KG 100, 200, 500, 600, 800, 900.

Organization of the card file. - At this point it might be well to describe how the card file is organized for ease in visualizing the array of KGG and their relationship to each other. The various KG numbers are printed on 1/5-cut index tabs. KG 1 is printed on a position-1 tab, and all second-level KG numbers arising *directly* from KG 1 are put on position-2 tabs. Third-level KG numbers arising directly from each of these will then be printed on position-3 tabs, etc. The array might eventually look like this (the front of the file is at the bottom):

	980
	960
	920
900	
	870
	820
800	
	750
	670
	650
600	
	570
	550
500	
	260
	230
200	
	150
100	
KG 1	

Because of the exponential increase in capacity of tabular keys with addition of new levels of key groups, I have not yet prepared one which goes beyond four levels, although eventually this is certain to occur. Theoretically all living taxa could be accommodated in fewer than 10 levels in a tabular key. It would, of course, be a rather large key.

The above arrangement of KGG in the card index parallels the arrangement of the statements of characters and the accompanying tables in the looseleaf notebook. These are arranged in strictly numerical sequence and the sheets are punched so that the statements of characters are on the left page, the tables on the right. Any illustrations necessary to supplement the statements of characters are placed in the spaces at the bottom of either page. The illustrations should be detachable so that they can be transferred to new pages if it becomes necessary to revise the statement of characters, or the table. Since these illustrations are directed at specific structural detail, they usually are not very comprehensive or complex. In the notebook, one additional notation saves time

in backtracking, which is sometimes necessary in tabular keys just as in dichotomous keys. The heading for each page, whether statements or tables, should include a notation of the immediate source of the KG in question, e. g.: MESOSTIGMATA KG 570 (ex 550), or KG 980 (ex 960), etc.

Procedures for second- and third-level KGG. - After KG numbers have been assigned for the second-level groups arising from KG 1, each of these is studied to determine which characters best separate the subtaxa within them. I have found it most useful to begin with the largest group, since the separation of a large number of subtaxa will usually bring to light more fundamental characters than would be necessary to separate small groups of subtaxa. The principles outlined for selection of KG 1 characters apply to second- and third-level KGG also. Certain characters will be useful in more than one KG, in which case the statements of variants and code symbols are transferred directly from one KG to another. However, they will not necessarily fall at the same level in the list of characters. Usually, more than 5 characters are tried initially, as one or more may be found unsatisfactory. As described for KG 1 (above), I do this preliminary work in rough form on 8 1/2" × 11" sheets or on 4"×6" cards, which are saved for reference purposes.

Once the characters have been selected and the statements of variants have been drafted, the data cards for that KG are pulled from the file, and the number of the KG is written in the column at the left margin, on the line below the formula for KG 1. The code symbols are then inserted, working from specimens or published descriptions, or both, as appropriate. The cards are then sorted again, as described for KG 1, and arranged in a logical sequence. This procedure is repeated for all second-level KGG.

Third-level and higher KGG are handled the same way, except that as one progresses beyond third-level KGG, the use of continuously-varying characters becomes more frequent.

At this point it should be explained that, if the key is being constructed from a study collection of specimens, the study collection should also be arranged in a manner corresponding with the organization of the card file and the KG tables. Presumed or known natural groupings should be ignored at this stage if these are found to conflict with the organization of a workable tabular key. Inconsistencies arising from splitting of such groupings can always be handled subsequently by a variety of cross-referencing systems. For example, if a generally useful character were found, on rare occasion, to send very closely related forms into separate parts of the key, these could be brought together again by assigning identical KG numbers at two different places in the key. Now combined in a single group, and separated from the other subtaxa, these forms can be separated from each other, using the same character which initially sent them to different parts of the key. An alternative is to simply leave the subtaxa in question at the points they come out in the key, and add explanatory notes in the appropriate table, e. g.

w t p 1 3 Taxon B, ♂ (♀ comes out in KG 435, formula e h t n 7)

ADDITIONAL FUNCTIONAL FEATURES OF TABULAR KEYS

Exploratory characters. - As a general rule, while selecting the characters for a parti-

cular KG, certain other characters which show promise of being useful in that or subsequent KGG will be perceived. These can be added at the end of the list of character statements. For example, if the final list of characters selected for a particular KG numbers 5, but there are two characters that you wish to explore further, add these as characters 6 and 7. It sometimes turns out that one of these will prove more useful than one of the initial 5, and that the other is more useful in some of the subsequent KGG. The first of these (say No. 6) can then be substituted for the least useful of the initial 5 characters (say No. 4). From an operational standpoint this is handled very simply. The statement of characters must be revised to reflect this, normally a simple stenographic task, by transferring the statement of character 6 to the number 4 position and *vice versa*. The data cards are then altered by transferring the symbols for character 4 to the number 6 position, and *vice versa*. Both characters 6 and 7 are now available for use in subsequent KGG, and since the data are already on the cards, it is not necessary to go back to the original materials (specimens or descriptions in the literature). All changes are made on paper.

Changes in the tables are effected by simply erasing the symbols for characters 4 and 6 and reversing them. This can be done with "liquid paper," which is now in common use in stenographic procedures, over-writing the new symbols in India ink. I follow the practice of maintaining a file of master copies which can be reproduced by Xerox or similar processes. These are revised periodically, from notations made on a Xerox copy, which is the actual working key.

Assuming that character 7 proves useful, but only in a subsequent KG, the data are already on the cards, and it only involves paper work to transfer these to the proper place in the desired KGG.

Exploratory characters can be shown (for information purposes) in the table, but they need not be used in establishing KGG. For example, the formulae:

$$\begin{array}{l} e \ h \ t \ n \ 3 \ / \ r \ 7, \\ e \ h \ t \ n \ 3 \ / \ s \ 2 \ \text{and} \\ e \ h \ t \ n \ 3 \ / \ s \ 3 \end{array}$$

can be considered identical, for purposes of establishing the KG numbers, although the important additional information on characters 6 and 7 is available for use as desired.

Difficult characters. - These include many types of characters of extreme value when available, but for which data are frequently unavailable. In the Halacaridae, for example, data on number of nymphal instars (1, 2 or 3) are of utmost systematic importance; likewise, characters confined to one of the sexes. Characters such as these cannot be used in dichotomous keys without greatly diminishing the utility of the key. In group-tabular keys, such data can be included in a way that actually enhances the value of the key. The data are simply introduced after the principal characters, in the same manner as the *exploratory characters* discussed above. If the data are available, they can be used to great advantage. If unavailable, their lack does not hamper the use of the key.

Also included here would be ecological data, information on hosts in the case of parasitic species, special environmental conditions under which the taxon is normally encountered, geographical distribution, seasonal information, biochemical data, etc. All

of these can be coded in one way or another.

Such characters should always come *after* the statements of the principal characters; never *within* the principal characters; i. e., they should stand in the No. 6 or 7 positions. Even if there is no No. 4 or 5 character, it is advisable to leave these positions blank, and insert "difficult characters" in the No. 6 and 7 positions, leaving space for the subsequent insertion of more convenient characters in the 4 and 5 positions.

The problem of missing characters. - In identifying organisms, inevitably specimens are encountered in which the variant, or state, of a particular character is not ascertainable. In dichotomous keys, this situation necessitates running the specimen down both branches of the ambiguous dichotomy, then making a value judgment between two choices at the end. Tabular keys do not eliminate this problem, but they simplify handling it. Frequently, a definite choice can be made even with data on one or more of the characters completely lacking. The example given below illustrates this. Assume the following array of formulae in a given KG:

c	t	p	o	+	KG 100
w	n	p	2	3	Taxon A
w	t	a	1	3	KG 200
w	t	a	1	+	KG 550
w	t	p	1	3	Taxon B
w	t	p	1	+	KG 800

Assume further that a specimen is found with the following indeterminate formula: $w ? a 1 +$. By simple inspection it can be determined that this specimen probably belongs in KG 550. The only alternative is that it is a new taxon not presently in the table.

In some cases it is even possible to make judgments on the basis of probability when more than one character is missing, by inspection of the table. For example, assume a taxon with the formula: $? t p o ?$. In a dichotomous key there would be 4 possibilities, and the mechanics involved in arriving at a decision are difficult, indeed. With a tabular key, in this particular case, there are only 2 possibilities: the taxon either falls in KG 100, or it is a new taxon, and this can be determined by rapid inspection. If the key is based on extensive experience, the probability of a new taxon is small, and little is likely to be lost by assuming that it belongs in KG 100.

Or, to take the ultimate example in the present case, it is conceivable that the formula could be: $? ? ? 2 ! ?$. Again, even on this scanty information only 2 possibilities exist. The specimen either belongs to Taxon A, or it is a new taxon. Such a situation would be virtually impossible to resolve in a dichotomous key.

The problem of multiple variants of a discontinuously varying character within exceptional taxa. - Occasionally a character exhibits clear-cut discontinuous variation in virtually all subtaxa of a particular taxon, but in rare exceptions two, or even three variants of that character may appear within a single subtaxon. Because of the practical problems involved, such characters are often avoided in dichotomous keys, or are employed only in those parts of the key where their use does not involve any complex qualifying statements. These cases can be handled more directly in tabular keys. The formula for the exceptional subtaxon (or subtaxa) simply includes the code symbol for all of the variants that are found there, e. g.

w t p 1 r KG 150
 w t p 4 s KG 175
 e r s 2 r subtaxon A
 e r s 1, 2, 4! s subtaxon B

If necessary, tracers can be set up whenever such variable subtaxa run to more than one terminal KG, explanatory notes can be inserted in the tables, etc.

Tabular keys and communication of information. - A well-constructed tabular key is valuable well beyond the utilitarian function of identifying specimens. The statements of characters in the early KGG should tell the user of the key: "These are, on the basis of experience, the most significant types of structural variation found in this particular group of organisms." In a very real way, they can be interpreted as a text, in shorthand form, of the comparative anatomy of the group.

As one approaches the terminal key groups, the sense of the information changes somewhat. The emphasis is now on the characteristics of individual subtaxa, and the variations that occur within these. Characters showing continuous variation are much more frequent, and the information ultimately becomes: "In subtaxon 5432-275 character No. 4 of KG 378 has been observed to range from .37 to .45 and to average .41, based on 6 measurements made on individuals collected at Matabungkay, Batangas, Luzon, Republic of the Philippines, September, 1967."

There is virtually no limit to the types of information that can be incorporated into tabular keys. The ultimate taxa may be slide numbers or specimen numbers in a particular collection. They need not be names of species or genera, etc. Theoretically, this type of information could be incorporated into dichotomous keys as well, but it is far easier to present in the form of tabular keys.

Location of specimens in large collections. - In a very large collection, it is not uncommon to find many of the specimens unidentified, even to family or genus. Often this is because reliable or convenient keys are not available. In my own collection of more than 200,000 mounted specimens of Acari, the majority are unidentified. I am now in the process of arranging this unidentified material, using tabular keys. The arrangement of most of the unidentified material will be by KGG, rather than by named taxa, since these taxa are not well known to me.

On numerous occasions I have been faced with the question: "Is a particular named taxon, not identifiable by me on sight, present in this collection?" Frequently this question arises when a well-described taxon appears in the literature, and I wish to locate specimens of it or closely related forms. A data card is prepared from the description in the literature, using the tabular keys for the appropriate order of the Acari. If the description is adequate, I can usually determine within a very few minutes whether or not I have the taxon or a close relative. Since these taxa are often not well known to me, the entries in my keys may be only slide numbers. And, since the slides for the unidentified material are arranged according to the formulae in the terminal KGG, they can be located immediately.

Tabular keys are invaluable aids in organizing collections for revisional studies. And, of course, they can be published, either in standard form, or in looseleaf.

Expansion of tabular keys. - When a new taxon is encountered, either in a collection

or the literature, a data card is prepared for it and added to the card file. The formula for the terminal key group is also inserted at the appropriate place in the table. Eventually, clusters of identical formulae for a number of different taxa appear at various points in the card file and the tables. When time is available, each of these clusters is replaced by a single line and a new KG number. A new set of characters is selected which will permit separation of a given cluster into discrete subtaxa. The statement of characters is then drafted, the cards for the taxa involved are pulled from the file, and the formulae for the new KG are added. The cards are arranged in a logical sequence and the table for the new KG is prepared. Both the statement of characters and the new table are inserted at the appropriate place in the looseleaf key, and the data cards are filed behind the new tab in the appropriate level in the card file.

Use of tabular keys in instruction. - I have now used tabular keys in classes in acarology over a period of several years. Reaction of students is typically guarded at first, since they are accustomed to dichotomous keys and find tabular keys a strange innovation. Dichotomous keys in books have the deceptive allure that all the taxa are neatly wrapped up between the first and last dichotomies, and students are sometimes slow to accept the idea that, in many groups, the best they can hope for is the specimen number and the vague promise that the new taxon will someday be named. Eventually and invariably, however, they realize the advantages of tabular keys, and accept them, sometimes with enthusiasm.

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