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Institution: Oklahoma A. and M. College

Location: Stillwater, Oklahoma

Title of Study: THE USE OF SIMPLE TAXONOMIC KEYS FOR STUDENT IDENTIFICATION OF COLLECTED SPECIMENS

Pages of Study: 42

Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: Student identification of collected specimens is usually a problem for high school biology teachers. Quite often their students must rely on a trial-and-error process of picture comparison or upon comprehensive taxonomic keys. Identification by trial-and-error methods offers little practice of the scientific method, and comprehensive taxonomic keys must of necessity employ terminology too complex for the average high school student.

Findings and Conclusions: One solution to the problem is for the teacher to write his own simple taxonomic keys. Capitalizing on the facts that the student is limited to a small area and collecting time and that more obscure forms will not make up the general collection, the teacher usually can write keys that will apply to most of the local specimens and can incorporate more superficial physical characteristics in these keys. The value of simple taxonomic keys does not lie solely in their use for identification. The student must have a fundamental knowledge of the morphology of his specimens in order to use a key. He must practice critical observation, and he must get an opportunity to conquer the unknown. Simple keys have their limitations. With keys that are of such a limited nature, one must expect to encounter exceptions. Practice has shown that the "exception" presents no real problem. The teacher can not expect to write a complete key in just one year. Patience and some hard work over a period of years can, however, provide keys that will help solve the problem of identification and provide a means for enriching the biology course.

ADVISER'S APPROVAL James H. Zant

THE USE OF SIMPLE TAXONOMIC KEYS FOR STUDENT IDENTIFICATION OF COLLECTED SPECIMENS

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Bachelor of Science

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Kirksville, Missouri

1953

Submitted to the faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1957

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ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to the staff of the Montana State University Biological Station and to Dr. U. T. Waterfall of Oklahoma A. and M. College for their moral support for the ideas expressed in this paper. Further credit is due Dr. James Zant for his patience and sympathy toward this project.

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PART I

INTRODUCTION

This is an original paper based largely upon experience and observation for the past three years at Mountain Home High School, Mountain Home, Idaho. The subject, however, is not new with many high school biology teachers.

Taxonomy has its place in a well-rounded biology course. This paper is merely an attempt to show one solution to that phase of it dealing with the problem of student identification of collected specimens. It has been designed to illustrate how a high school biology teacher, who must of necessity be a "jack-of-all-trades," can write his own simple identification keys and to show some of the inherent advantages of this method.

PART II

STUDENT USE OF KEYS

In order to better acquaint students with their natural environment, biology teachers often require their students to find and collect certain inhabitants. The collections vary, of course, from one school to the next, but most biology teachers have one common problem in regard to these collections--enabling the student to make a quick and accurate identification of his specimens.

Identification of collected specimens is not the primary objective of such an assignment, but for the maximum benefit to be attained from such a collection, the student must be able to give his specimens some kind of a name. Names bring order out of confusion. Just as one knows the name of a person and so can then learn more about him (or her), so the naming of these inhabitants serves as a basis for a study of structure, life history, ecological distribution, and economic importance.

Various methods have been used by high school teachers of biology for student identification. One that is quite common has the student simply rely on his past knowledge or the knowledge of some of the "community biologists" for naming his specimens. If the teacher is not too concerned with proper identification, this method might be satisfactory. There are numerous limitations. Many of these "community biologists," such as the county agent, forest ranger, or soil conservationist, are most concerned with the plants or animals that affect the economy of the area, while their knowledge of forms of less economic importance is generally limited. In some communities they may rely on the high school biology teachers for identification services.

One of the most common methods used by high school biology teachers for student identification is that of random picture comparison. This seems to be especially typical in biology classes where the teacher has had little or no experience with plant or animal identification. The general procedure is for the teacher to make available all of the picture identification books that the budget will afford and then let the students "thumb-through" until they see a specimen that compares with the one they are trying to identify. Picture comparison has its advantages in simplifying the identification process, but this method alone, as an exercise for using the scientific method, most surely would fail. It is quite possible to make an accurate identification in this manner however. Nevertheless, it is only a coincidence, and this trial-and-error process is often very time consuming and quite frustrating, especially for a student who has to wait until he "gets the book." Even after the student has made some kind of an identification by this process, he actually has gained little knowledge of the individual specimen. For example, it is possible to tell the difference between a squash bug and a ground beetle by comparing a picture of their dorsal views, but the student who has done this has no knowledge of the difference in the mouthparts of the two. Without a knowledge of their mouthparts, the student cannot begin to understand their respective habitats or the role they play in their natural environment.

The method of identification most often used by advanced students and trained taxonomists is by the use of comprehensive taxonomic keys for the special group with which they are concerned. A taxonomic key might be defined as a concise summary of the individuals and their characteristics, so arranged that by comparing the unknown specimen with these characters, the student can, by the process of elimination, arrive at the characters which fit his specimen. Postal employees use a system vaguely similar to this for locating and identifying almost any individual that inhabits the earth. Let us see how an ordinary postal address can illustrate this identification process.

Mr. John Smith
114 W. Maple St.
Stillwater, Oklahoma
USA

USA automatically eliminates this individual from all of the millions of people that live in the different countries of the world. Oklahoma eliminates him from the other forty-seven states and territories, and Stillwater further eliminates him from the other cities of this state. Maple St. isolates him from the other areas of the city and the surrounding rural area, and W. Maple St. eliminates half of the one street. The number 114 designates one specific house in which Mr. Smith resides, and, for the sake of convenience, we will assume that postal employees do not contend with two individuals with like names.

Postal employees and biologists are not the only people who have seen fit to use such a system of identification. Chemists long have used such principles in their various schemes of analysis. Geologists use such a system for identifying their rocks and minerals. Pedologists have elaborate keys for identifying the different soil types. It should be emphasized at this point, however, that taxonomy is a complex science. In the course of this paper, many very superficial concepts will be developed. It is implied that external physical characteristics are the sole basis for classification. This is an absolute misconception. Modern taxonomy is based upon blood relationships between natural populations, and taxonomic distinctions are based on physiological and chemical relationships as well as external and internal morphology. Genetics and embryology have an important place in the classification of living organisms.

It is further implied that classification is based upon some "type" specimen that has been described thoroughly and filed away in some remote depository. This is not the modern concept. Classification today is based upon natural populations and the similarities and differences between these populations. It must be positively stated that the only realm of taxonomy that this teacher advocates invading is that superficial phase of identification that makes use of only the most obvious external physical characteristics.

There are numerous problems facing a high school biology teacher who might use taxonomic keys in his classroom. In order for a key to be worthy of publication, it must of necessity be a comprehensive key which encompasses a wide area and large groups of diversified specimens. Since insects and flowers do not have specific mailing addresses, a taxonomist must use a large number of characters, many of which are too obscure or complex for the average high school student to recognize or understand.

Another problem for most biology teachers is the expense of purchasing comprehensive keys for their students to use. Although there are many good comprehensive keys published today in the "low-price" category,[1] it still amounts to quite an expense to equip each student with his own key.

The most logical solution, it seems, is for the biology teacher to write his own keys. This might seem like an impossibility to many biology teachers who have enough trouble mastering a key that has been written by a trained taxonomist, but let us look at some facts which tend to

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[1]Consult Appendix for a listing of these.

simplify the problem considerably. Let us use the example of a key to the spring wild flowers of a given area. First of all, the students will be collecting flowers that are in "bloom" over a relatively short period of time. Quite often this period of time is limited to the last weeks in April and the first weeks in May. This, then, eliminates all of the other flowers that are in "bloom" during the summer months. Secondly, the student generally is confined to a rather small area around his community. This further narrows the total number of flowers that he might find. The practicality of teacher-made keys is based primarily on the facts that student collecting is limited to area and season and, in addition, a very large majority of the specimens collected will be the most common inhabitants of the area.

The first big problem that confronts the teacher who might want to construct keys for use by his students is the very obvious fact that many teachers simply do not know how to use taxonomic keys themselves. This is especially true of teachers who are "stuck" with teaching biology along with the other science courses with which they are more familiar. The most important point to bring out is that there are many comprehensive keys that are available today that are designed for the _amateur_ collector,[2] and in order to learn how to use a key properly, these teachers are referred to these works. We will in the course of this paper, however, refer to many

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[2]Consult Appendix for a summary of these.

of the basic principles, and a teacher with little or no training in taxonomy should not feel handicapped in this regard.

Another problem that accompanies the use of a key, that of confirmation, or knowing for sure that identification of a specimen is correct, is likely to cause the teacher with little experience some anxiety. Confidence in one's ability, just as with any skill, comes with experience and practice. No one individual can assure himself that he has made a positive identification. Trained taxonomists often are not sure of the name they might place on an individual. To be sure, many of the problems of taxonomists today are the result of incorrect identification. We all have heard of the "lumpers" and the "splitters." If the high school teacher has a serious problem relating to identification, it is usually advisable to rely upon the assistance of a specialist at one of his nearest colleges. Most college taxonomists are friendly and are usually more than willing to help a struggling high school teacher with problems of identification. Ethics require, however, that they keep at least one of the specimens for their own collections, but this is a fair bargain for such service.

Assuming, then, that the biology teacher does have a fair ability to use a taxonomic key and desires to make simple keys for his students, the next problem that presents itself is to what level of classification must the keys be written. Generally with the insects, it is desirable to identify them to the Family level.[3] Order separates the beetles from the true bugs, but Family separates the "diving beetles" from the "blister beetles." With the flowering plants, it is often necessary to get the plant "down" to the Genus or species level before the name becomes meaningful for the student. Family Liliaceae tells us little about a plant. Genus Allium tells us that this plant is a "wild onion," while, with another lily, Fritellaria pudica tells us that we have a "yellow-bell." The taxonomic category, then, must be determined by the teacher. Of course, it is most desirable to give a plant or animal its complete scientific name, but with some groups this can be done only by trained taxonomists with years of experience with the individual groups. Even these men quite often must refer to detailed monographs and other obscure literature. Our level of classification must be a compromise with literature that is available and our ability to adapt it to student use.

At this point one might wonder why a teacher should go to so much trouble just to enable students to tag a plant or animal with a scientific name. A first impression might be that we are training our students to become successful taxonomists. To save this teacher from being branded as a "systematist," it is probably worth a few words to outline

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[3]There are notable exceptions, e.g., Order Odonata taken to the Sub-orders separates dragonflies from damselflies, while Order Dermaptera alone tells us we have an earwig.

some of the basic philosophy behind this approach to the teaching of biology.

It is this teacher's opinion that many of us have been "frauding" the public by accepting their tax money under the pretense of teaching our students about their natural environment with many of our methods. During the sunny weeks of September, we use prepared slides of Spirogyra and Elodea to develop the cell concept, and during the stormy month of January we break out with our pickled grasshoppers to acquaint our students with the world of insects. We pride ourselves with the number of microscopes that we have managed to squeeze out of our administrators' budgets, and our students have learned their value in their artistic training. Some of our better students even learn that "Turtox" is the place "where all this stuff grows."

In order to study our natural environment, we must "get in it." We can bring certain segments of it inside the classroom in the form of aquaria or terraria, or in the form of embalmed specimens, but we must get the students outside. We do this, of course, with supervised field trips, but this teacher maintains that it is further worthwhile for the students to go searching for various inhabitants on their own initiative. Most high school students seem to look upon this as a great personal challenge to their ability and get tremendous satisfaction from finding and collecting. This teacher can cite one example which might illustrate this.

Near Mountain Home, Idaho, there are many vegetation zones, and each has its characteristic spring flora. What many of the students do not realize is that quite often many of the plants at the higher and cooler elevations will flower before many down in the valley or on the plateau. In order for them to appreciate this, it would be necessary to conduct a field trip up the side of Bennett Mountain, the base of which is approximately fifteen miles from the school. Instead of organizing such a time consuming field trip, the students were advised one Friday that about 1,000 feet up the mountain could be found a very interesting member of the "Mustard Family" (Whitlow Grass, Family Cruciferae, Genus Draba), and it would be an interesting member to include in one's collection. They were advised further that it would involve quite a climb, and even then it probably would be difficult to find. (It is rather difficult to locate because of its low spreading habits.) Anyone who has worked with high school students could predict easily the results of such a challenge. On the following Sunday afternoon, one might think that a hot-rod session was being held some place at the base of Bennett Mountain. The hillside was literally swarming with biology students and some of the upper classmen who "knew where they had found it." The humorous part of this story is that there were several mothers and fathers (who had been codgled into taking the car) who were eagerly seeking the elusive "Whitlow Grass." Sometimes this makes the teacher wonder who is getting the most fun out of such an expedition. Actually, parents make very good "bug" collectors, too. Lest some teacher worry about the conservation of "Whitlow Grass," it should be pointed out that the plant is quite plentiful in the general area and that students look upon a student who "needs a whole handful of the stuff to identify it" as being a "real square."

Observing plants and animals in their native habitat, then, is one of the desirable objectives for student collecting. Most of us have had to listen to long discussions regarding the importance of recognizing form before function. This sequence becomes a pattern with students making plant and animal collections. Fathers are well aware of the type of questions asked by their children after a visit to the zoo. Why still remains in the vocabulary of high school students, and student collecting seems to be a very effective stimulus to study, discussion, and further exploration into the mysteries of their environment. One very disturbing consequence which bothers us at times is that they enjoy themselves, and this is definitely not in character with the traditional high school.

Proper identification of the collected specimens is the next step with these collections and, of course, the subject of this paper. The various methods have been discussed as well as the necessity for arriving at some kind of a name. Simple taxonomic keys written by the instructor, and designed for his students, seem to be the simplest and most scientific way to solve the problem. There are many subtle advantages in using the taxonomic key that might well be brought to light.

In order to use a taxonomic key, a student must have a good basic knowledge of the morphology of the group with which he is working. He must exercise time and again that most fundamental part of the scientific method, accurate observation. He must rely on his knowledge and powers of observation in order to make intelligent decisions. He gets the opportunity to work with and overcome the "unknown." One might give a liberal interpretation and look at the sequences in a taxonomic key as representing a series of "scientific problems."

We all pride ourselves with the ability to "explain" the parts of a flower and the function of the various floral parts. In our tests we never fail to make reference to such choice information. Yet, do our students really understand the function of the petals, stamens, and pistil? Six weeks later, would they even know what they were if they saw them? Would not the student who has observed and has counted stamens, and has determined the placement of the placenta in the ovary, not have a more lasting understanding of the importance of the flower as a means of continuing the existence of the plant? Would not our unit on reproduction become more meaningful? Would not the student who has observed the needle sharpness of the "Assassin-bug's" mouth-parts and the dense hair on the legs of the "house-fly" not have a better understanding of the role these creatures play in their natural environment? Taxonomic keys that are simple enough for the student to use can be very effective teaching tools. Any teacher knows that application of knowledge is the most effective means for remembering. A simple taxonomic key serves as an excellent means for the high school biology student to apply some of the knowledge that we insist he needs to remember.

Making taxonomic keys requires a certain amount of time and hard work, as the reader undoubtedly has concluded. The teacher, of necessity, must be constantly working to become more familiar with his environment. This is true, however, whether the teacher feels that taxonomy is worthwhile or not. It only makes common sense that the teacher must make some attempt to understand and observe his environment if he expects to guide his students toward that end.

PART III

MAKING A SIMPLE KEY

If the reader still has the courage to continue, let us proceed to construct one of these simple keys. Maybe we can make this task seem less frightening. Let us assume that we might have some reason to make a key to eight of the common Orders of insects. Since these insects exhibit both winged and wingless forms, we, for the purposes of simplification, will concern ourselves with only those forms that exhibit some kind of wing structure.

The first step in the construction of our key is to avail ourselves with all of the information possible that is pertinent to our groups and write the fundamental characteristics down opposite each group. Where could we find this information? With the insects that we have selected, this information generally is included in most good high school biology texts. If not there, any general entomology textbook would serve. Another general source of information quite often overlooked is the encyclopedias that almost any high school library will have. Many of these encyclopedias carry very thorough discussions of some of the major groups of plants and animals. The initial stage of our key, then, would appear as follows:

Order Orthoptera--two pair of wings folded over the abdomen, unlike in structure, the forewings parchment-like with veins, the hind wings membranous and larger than the forewings; chewing-biting mouthparts; incomplete metamorphosis. Grasshoppers, Roaches, and Crickets.

Order Dermaptera--two pair of wings, generally very short, covering only one or two segments of the abdomen; abdomen fitted with forcepts-like appendages at posterior end; chewing-biting mouthparts; incomplete metamorphosis. Earwigs.

Order Hemiptera--two pair of wings folded over the abdomen with the membranous tips of the forewings overlapping; forewing mostly hard and leathery without veins; piercing-sucking mouthparts; incomplete metamorphosis. True bugs.

Order Neuroptera--two pair of wings, both pair membranous with many veins and cross-veins; chewing-biting mouthparts; complete metamorphosis. Lacewings and Mantispids.

Order Hymenoptera--two pair of wings, both membranous with few veins and few cross-veins; mouthparts variable among the members; complete metamorphosis. Bees, Wasps, and Ants.

Order Coleoptera--two pair of wings folded over the abdomen and meeting in a straight line down the back; forewing thick and leathery, without veins, hind wing membranous (and inconspicuous due to thickness and rigidity of forewing); chewing-biting mouthparts; complete metamorphosis. Beetles.

Order Lepidoptera--two pair of wings, similar in structure, covered with scales; mouthparts generally reduced to a long coiled siphoning tube (maxilla); complete metamorphosis. Butterflies and Moths.

Order Diptera--one pair of membranous wings; few veins and cross-veins; mouthparts variable from piercing-sucking to sponging-lapping; complete metamorphosis. True Flies and Mosquitoes.

The next step is to study the characteristics of each Order to determine a single characteristic that would separate them into two groups. Generally, the procedure is to divide the groups into two nearly equal sub-groups, but this is not always possible or desirable. This is the procedure that will be followed with our key.

Let us look at some of our possibilities for dividing the groups. We find that the Orders Orthoptera, Dermaptera, Neuroptera, and Coleoptera exhibit chewing-biting mouthparts, while the Orders Hemiptera and Lepidoptera exhibit mouthparts of the piercing-sucking or siphoning variety. Orders Hymenoptera and Diptera, however, may exhibit different types, so mouthparts would not be suitable for a first division.

Looking further, we find that seven of the Orders exhibit two pair of wings, while Order Diptera comes equipped with one pair. Order Dermaptera is the only Order which exhibits forceps-like appendages at the posterior end of the abdomen. These Orders could be separated using either of the characteristics, but we will still try and find a single characteristics which will divide the groups into nearly equal halves.

Further examination reveals that we have five Orders, Orthoptera, Dermaptera, Hemiptera, Coleoptera, and Lepidoptera, that have forewings that are, for the most part, not membranous; three Orders, Neuroptera, Hymenoptera, and Diptera, have wings that are completely membranous. Type of metamorphosis is irrelevant to our key since the adult forms do not exhibit any obvious character that would reveal the history of their development.

We can, then, on the basis of forewing structure, divide the group as follows:

Forewings completely membranous

Order Neuroptera

Order Hymenoptera

Order Diptera

Forewings not completely membranous; hard and leathery, parchment-like, or with scales

Order Orthoptera

Order Dermaptera

Order Hemiptera

Order Coleoptera

Order Lepidoptera

The next step is to separate the first sub-group, Orders Neuroptera, Hymenoptera, and Diptera. The most obvious difference between them is that Diptera is characterized by one pair of wings while Hymenoptera and Neuroptera both have two pair of wings. Hymenoptera can be separated from Neuroptera by the relative number of veins and cross-veins. Hymenoptera has few veins and cross-veins while Neuroptera has many veins and cross-veins. Incorporating these into our key then, it would appear as follows:

Forewings completely membranous

One pair of wings present..Order Diptera

Two pair of wings present

Wings with few veins and cross-veins..Order Hymenoptera

Wings with many veins and cross-veins..Order Neuroptera

Forewings not completely membranous; hard and leathery, parchment-like, or with scales

Order Orthoptera

Order Dermaptera

Order Hemiptera

Order Coleoptera

Order Lepidoptera

Applying the same procedure to the second sub-group, we must find a way to separate the remaining five Orders. Again, there are several possibilities. Wing differences could be used since this is one of the most obvious differences between them. If one desires the key to serve only as an instrument of identification, wing characteristics would serve effectively. If, on the other hand, the teacher feels that it is more desirable to incorporate characteristics, where possible, that require a more thorough observation of the insect, it is probably more worthwhile to include these. Since the student must observe the wings of his insect while making his first choice, we can use mouthparts to separate our second sub-group. Orders Orthoptera, Dermaptera, and Coleoptera are equipped with chewing-biting mouthparts, while Hemiptera and Lepidoptera exhibit the piercing-sucking or siphoning variety. Using these characters, our next stage of development would appear:

Forewings completely membranous

One pair of wings present..Order Diptera

Two pair of wings present

Wings with few veins and cross-veins..Order Hymenoptera

Wings with many veins and cross-veins..Order Neuroptera

Forewings not completely membranous; hard and leathery, parchment-like, or with scales

Mouthparts chewing-biting

Order Orthoptera

Order Dermaptera

Order Coleoptera

Mouthparts piercing-sucking or siphoning

Order Hemiptera

Order Lepidoptera

We must now separate Orthoptera, Dermaptera, and Coleoptera. The most obvious and fundamental difference between them is that Dermaptera has two "pincer-like" appendages projecting from the tip of the abdomen while the other two do not. Orthoptera and Coleoptera can be separated by wing structure. Orthoptera is characterized by parchment-like forewings with veins, while Coleoptera has forewings that are hard and leathery without veins.

Hemiptera and Lepidoptera can be separated by mouthparts and wing structure. Hemiptera is characterized by forewings that are mostly hard and leathery, with membranous overlapping tips and mouthparts of the piercing-sucking variety with a sharp pointed beak. Lepidoptera has wings that are large and covered with scales and mouthparts consisting of a long coiled siphoning-tube. With these characteristics in our key, it would appear:

KEY TO EIGHT COMMON ORDERS OF INSECTS

Forewings completely membranous

One pair of wings present..Order Diptera, True Flies and Mosquitoes

Two pair of wings present

Wings with few veins and cross-veins..Order Hymenoptera, Bees, Wasps, and Ants

Wings with many veins and cross-veins..Order Neuroptera, Lacewings and Mantispids

Forewings not completely membranous; hard and leathery, parchment-like, or with scales

Mouthparts chewing-biting

End of abdomen with two "pincer-like" appendages..Order Dermaptera, Earwigs

End of abdomen without two "pincer-like" appendages

Forewings parchment-like, with veins.. Order Orthoptera, Grasshoppers, Roaches, and Crickets

Forewings hard and leathery, without veins..Order Coleoptera, Beetles

Mouthparts piercing-sucking or siphoning

Mouthparts a sharp pointed beak; forewings hard and leathery with membranous overlapping tips..Order Hemiptera, True Bugs

Mouthparts a long coiled siphoning tube; wings large and covered with scales..Order Lepidoptera, Butterflies and Moths

For all practical purposes, we might call our key complete at this state. When designing a key to be used by high school students, however, it is wise to analyze it with some of the following questions in mind. Are there any confusing terms in the key that students are not likely to understand? Is the key accurate and what are its limitations? Is considerable magnification necessary to determine a proper choice? In the key that we have just made, let us try and answer these questions.

As best as can be determined, the key is accurate. Very seldom is a taxonomic key constructed, however, that is all inclusive. We have designed it for only the winged forms of eight specific Orders. There are exceptions among all groups of organisms, especially with the insects. This will be discussed later.

Is it confusing? Let us see. The first choice that the student encounters, "Forewings completely membranous," introduces a word which the student is not likely to quite understand. Membranous generally implies thin plant or animal tissue. With the special use of the word in entomology, however, it further implies tissue that is thin and more or less transparent. We can either define this new word for the student, or we can substitute for it in the key. Since the average tenth grade student has been introduced to the words transparent, translucent, and opaque, in his general science course, we might substitute these words wherever possible to give him a chance to apply what he already has learned.

The next choice that might appear confusing is determining whether an insect has few veins and cross-veins or many veins and cross-veins. This character is quite striking, however, and practice has shown that this decision is a very good exercise for critical observation. The student, of course, must know what veins and cross-veins are, but we will assume that this concept will be explained during any general discussion of insect anatomy.

The second "half" of our key is also worthy of revision. Since the forewings that are hard and leathery are also opaque, and the parchment-like wings of Orthoptera can be described as translucent, we may add or substitute these words to emphasize our characters.

Experience has shown further that the word scales when applied to insects has a tendency to cause confusion for beginning students. The student generally thinks in terms of fish scales when confronted with the term, and in a sense he is correct in that the insect scales do overlap. In most cases though, this overlapping is observed only with magnification, and even though it is desirable for this character to be observed at some time during the study, it is probably worthwhile to find some means of modifying the word. Macroscopically, the scales on Lepidoptera appear "fur-like" or "fuzz-like," and this "fur" can be rubbed off in the hand so that it appears like dust or lint. We may add, then, the words fur-like to modify <u>scales</u> and make the choice a bit more meaningful.

Problems of magnification do not apply to this particular key, since all characteristics are, for the most part, quite obvious. It may be desirable for the student to use magnification to determine mouthparts, or to examine a very small specimen, but the characters we have selected generally are visible with little difficulty.

The "indented" type key has been deliberately used to illustrate this first attempt at key making. This teacher believes that, for a relatively small number of specimens, this type is easiest for beginning students to use. There are numerous types of keys that could be used, but they differ primarily only in their physical construction.

Incorporating the revisions in our key, the final form would appear as follows:

KEY TO EIGHT COMMON ORDERS OF INSECTS

Forewings completely transparent

- One pair of wings present..Order <u>Diptera</u>, True Flies and Mosquitoes
- Two pair of wings present
  - Wings with few veins and cross-veins..Order <u>Hymenoptera</u>, Bees, Wasps, and Ants
  - Wings with many veins and cross-veins..Order <u>Neuroptera</u>, Lacewings and Mantispids

Forewings not completely transparent; opaque, translucent, or with fur-like scales

Mouthparts chewing-biting

End of abdomen with two "pincer-like" appendages..Order Dermaptera, Earwigs

End of abdomen without two "pincer-like" appendages

Forewings translucent, with veins..Order Orthoptera, Grasshoppers, Roaches, and Crickets

Forewings opaque, without veins..Order Coleoptera, Beetles

Mouthparts piercing-sucking or siphoning

Mouthparts a sharp pointed beak; forewings hard and opaque with transparent overlapping tips..Order Hemiptera, True Bugs

Mouthparts a long coiled siphoning tube; wings large and covered with fur-like scales.. Order Lepidoptera, Butterflies and Moths

PART IV

EXPANSION OF THE KEY AND ITS LIMITATIONS

Now that we have constructed a simple key, it is probably worthwhile to show how our effort with the insects could be expanded. Since the students will bring in many insects that are in the nymphal stage of development, without wings, it is desirable that any key should include these forms. In addition, there are some adult insects that do not exhibit wings, at least at some time during their adult life. Ants are a good example. The simplest procedure for adding this to our key would be to make the first choice read, "Wings absent" or "Wings present" and then proceed under "Wings absent" to arrange those forms in the same manner that we have done with the winged forms. The teacher also might find it desirable to include a few more Orders in his key. This generally would depend upon the locality of the school and the time of year that the students are collecting. A teacher located in the middle of a desert region would have little need to include Orders Plecoptera (Stoneflies) or Ephemerida (Mayflies). The ambitious teacher might even wish to add a few illustrations to further simplify the choices in the key.

Further classification to Family would be the next logical step. The same principles apply. Whereas more comprehensive keys must rely on rather obscure morphological characteristics, we may capitalize on our limited number of specimens to include more obvious features. For example, this teacher has found that over the past three years at Mountain Home High School, during the weeks from September 15 to October 15, a total of twelve Families of Coleoptera have been collected by the students. Coleoptera is the largest Order of insects, and this number in no way implies that twelve Families are all that can be found in the area at that time. This figure simply is taken from what the students have included in their collections. By using more obvious characteristics such as "Forewing one solid color" as opposed to "Forewing with spots, splotches, or stripes of different colors," it is possible to separate the Families Cicindelidae (Tiger Beetles), Coccinelidae (Lady Bird Beetles), and Chrysomelidae (Leaf Beetles) from the other Families. With the choices, "Legs modified for swiming" as opposed to "Legs not modified for swimming," the Families Hydrophilidae (Water Scavenger Beetles) and Dytiscidae (Diving Beetles) can be separated further.

It should be emphasized emphatically that such superficial characteristics will apply only to a very limited number of insects. There are thousands of insects that display different colored wing markings. Even in this teacher's locality, should the student do "advance collecting" during the summer months, he probably would have members of the Families Meloidae, Cerambycidae, and Silphidae, all of which have members that display multi-colored elytras (forewings). These are problems with which the teacher must learn to live when attempting to use keys that are so limited in nature. This is not, however, a problem that concerns only high school teachers. Most trained taxonomists will admit that there is no "perfect key." The more "popular type" keys usually are described by their authors as being designed for the average collector, and less common groups are omitted.

With taxonomic keys that are so limited to area and season, one should expect to encounter variations and exceptions. Lest some teacher be discouraged by this before attempting to use keys of his own design, this teacher can say only that it has been his experience that such exceptions actually present little difficulty or confusion, and if the students fully realize the limitations of their key, they take great delight in encountering a specimen that is not included. Interest is further maintained by permitting the student to find a place to include his specimen in the key (if the specimen is from our locality and seasonal), and students seem to take great pride with this opportunity for "authorship." Further satisfaction is gained by placing the student's name on the tag accompanying the new specimen.[4]

The teacher that never has used taxonomic keys in his classes might wonder just what type of student would succeed with this type of pedagogy. When the subject is mentioned for the first time to some teachers, the most frequent comment is that these keys are probably best used by the average or better than average student. This teacher does not wish to attempt a definition of an average student, but experience has shown that below-average or slower students seem to enjoy working with keys as much as some of the better students. They find that this is an area where they can compete readily with the better students, and they seem to enjoy themselves thoroughly. Of course, it is one of the ideals in education to let students compete with themselves, or with a group of their own capabilities, and this phase of the laboratory work in biology seems particularly well suited to this end.

In conclusion, this teacher would like to present one of his keys that has been designed for the students of Mountain Home High School for the identification of the spring wild flowers of that immediate area that are collected during the last half of April and the first half

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[4]It has been found worthwhile to mount all of the insect specimens (and flowers) in Riker type mounts without names and display them during the period of time the students are working with the group.

of May. This is the "second revision" of the spring flower key and serves to illustrate the text of this paper. Of course, it is of value only for that immediate area and time, but it is an example of such a teacher-made key, and its prototype, which was far more complex, has stood the test of actual student use. Some of the members have been included only to the Family level, some to the Genus level, and some to species. Further work must be done with this key as the years go by and as more experience is gained with some of the more complex families.

KEY TO THE SPRING WILD FLOWERS NEAR MOUNTAIN HOME, IDAHO

Plants monocotyledon; flower parts in 3's; leaves parallel veined

Ovary superior; stamens 6..Family Liliaceae

Ovary inferior; stamens 3, or united with the pistil

Stamens 3; flowers pinkish-purple; regular..Family Iridaceae

Stamens united with the pistil; flowers various colors; always irregular..Family Orchidaceae

Plants dicotyledon; flower parts in 4's or 5's; leaves netted veined

Plants shrubs; stems with woody tissue

Plants bushing or tree-like; leaves without thorny margins

Stamens numerous (more than 10)..Family Rosaceae

Stamens 5; petals yellow..Family Saxifragaceae

Plants low shrubs with pinnately compound leaves, the leaflets with sharp teeth on the margins; petals yellow..Family Berberidaceae

Plants herbs; stems not woody

Petals separate or nearly so

Flowers with few to many separate pistils.. Family Ranunculaceae

Flowers with 1 simple or compound pistil

Stamens 10 (sometimes 9-11)..Family Leguminosae

Stamens 5 or 6

Stamens 6, petals 4

Stamens shorter or not much longer than petals; ovary 2-celled; petals various colors..Family Cruciferae

Stamens almost twice as long or longer than petals; flowers yellow..Family Capparidaceae

Stamens 5, petals 5

Sepals 2..Family Portulacaceae

Sepals 4 or 5

Petals deeply cleft with a jagged appearance, pinkish-white..Family Saxifragaceae

Petals not jagged; petals brightly colored

Petals irregular; ovary 1-celled; stamens with broad filaments surrounding ovary.. Family Violaceae

Petals regular; ovary 5-celled; pinkish-purple..Family Geraniaceae

Petals united for most of their length

Ovary superior or nearly so

Petal lobes irregular

Ovary 2-celled and many seeded; style arising from top of ovary; stems round..Family Scrophulariaceae

Ovary appearing 4-celled and 4-lobed with 4 seeds; style arising out of a "pocket" in the top of the ovary; stems square.. Family Labiateae

Petal lobes regular or nearly so

Ovary 3-celled; style generally 3 cleft; petal lobes pink to white..Family Polemoniaceae

Ovary appearing 4-celled and 4-lobed; stems and leaves covered with dense hair..Family Boraginaceae

Ovary inferior; flowers in dense heads; the anthers united in a ring around the style..Family Compositae

FURTHER CLASSIFICATION OF SPRING FLOWERS

LILIACEAE

Style wanting; stigma sessile to ovary..Genus Calochortus, "Sego-Lily"

Styles present, 1 or 3

Style 1

Flowers white; crushed stem with onion-like odor.. Genus Allium, "Wild Onion"

Flowers yellow, nodding..Fritillaria pudica, "Yellow Bells"

Styles 3; flowers cream-white..Zigadenus paniculatus, "Foothill Death Camas"

IRIDACEAE

Stamens 3; flowers pinkish-purple..Sisyrinchium inflatum, "Grass Widows" or "Blue-eyed Grass"

ORCHIDACEAE

(Students have not collected any members of this family yet, but it is included in this key because its members are quite often represented in spring flower collections.)

ROSACEAE

Flowers white..Genus Amelanchier, "Service Berry"

Flowers yellow..Genus Purshia, "Bitterbrush"

SAXIFRAGACEAE

Plants shrubby; petals yellow..Ribes aureum, "Golden Currant"

Plants not shrubby; petals white-pink, very jagged.. Lithophragma bulbiferum, "Sawtooth flower"

BERBERIDACEAE

Plants low shrubs with pinnately compound leaves, the leaflets are thick and tough and appear shiny. Margins of leaflets with sharp teeth; petals yellow..Berberis repens, "Oregon Grape"

RANUNCULACEAE

Petals irregular and purplish-blue..Genus Delphinium, "Larkspur"

Petals regular and not purplish-blue

Petals yellow to yellowish-green, easily falling off; many pistils..Genus Ranunculus, "Buttercup"

Petals brown to reddish, thick and leathery, 3-5 pistils..Genus Paeonia, "Wild Peony"

LEGUMINOSAE

Filaments of 9 stamens united, 1 stamen free, erect herbs; leaves palmately compound..Genus Lupinus, "Lupine"

Filaments of stamens all united; low spreading herbs; leaves pinnately compound..Genus Astralagus, "Milk Vetch"

CRUCIFERAE

A large and complex family, with many spring forms in our area. Further classification has not been worked out.

CAPPARIDACEAE

Stamens almost twice as long or longer than the petals, often coiled; petals yellow; ovary 1-celled..Cleome lutea, "Yellow Bee Plant"

PORTULACACEAE

Two green sepals; 2 opposite leaves just below the inflorescence; petals pink to white..Claytonia lanceolata, "Spring Beauty"

VIOLACEAE

Petals irregular; ovary 1-celled; stamens with broad filaments surrounding ovary; petals many different combinations of blue, dark purple, violet, and yellow..Genus Viola, "Wild Violet"

GERANIACEAE

Petals regular; ovary 5-lobed and 5-celled, lengthening near maturity to form a long beak; petals pinkish-purple.. Erodium cicutarium, "Storks Bill"

SCROPHULARIACEAE

Stamens 5 with 1 of them sterile and hairy..Genus Penstemon, "Beard Tongue"

Stamens 4

Petals yellow or pinkish (if yellow, with brownish dots) ..Genus Mimulus, "Monkey Flower"

Petals reddish to orange; upper leaves partly colored like petals..Genus Castilleja, "Indian Paint Brush"

BORAGINACEAE

This family included for the same reasons as ORCHIDACEAE

POLEMONIACEAE

Ovary 3-celled; style generally 3 cleft; petal lobes pink or white; plants growing in large colonies..Genus Phlox, "Phlox" or "Wild Sweet Williams"

COMPOSITAE

A large and complex family, with many spring forms in our area. Further classification has not been worked out.

WILD FLOWER ANALYSIS FORM

TYPE OF PLANT
tree--shrub--herb

TYPE OF LEAF
simple--pinnately compound--
palmately compound
parallel veined--netted veined
alternate--opposite--whorled--basal

SEPALS
number of sepals____
color of sepals__________

PETALS
number of petals____
color of petals__________
united--separate
regular--irregular

STAMENS
number of stamens____

PISTIL
number of pistils____
each pistil:
number of stigmas____
number of styles____
ovary superior--ovary inferior

Specimen number____

Name______________

Where collected____

____

____

Date Collected_____

Family____________

Genus_____________

Scientific name____

____

Common Name________

____

- -

The analysis form above is filled out by the student for each of his wild flowers before an attempt is made to key the specimen out. These forms (mimeographed on half-sheets) then are pasted in the scrapbook opposite the mounted flower to serve as a concise summary of the individual flowers.

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Davis, Ray J. Flora of Idaho. Dubuque, Iowa: William C. Brown Company, 1952.

Lawrence, George H. M. An Introduction to Plant Taxonomy. New York: The Macmillan Company, 1955.

Ross, Herbert H. A Textbook of Entomology. New York: John Wiley and Sons, Inc., 1949.

APPENDIX

APPENDIX

There are numerous references that a high school biology teacher might use to help solve the problems of identification. The purpose of this appendix is to present a selected group of references that can serve as a good low-cost reference library of comprehensive keys. The Picture-Key Nature Series published by William C. Brown Company represents the combined efforts of some of the leading taxonomists in this country and offers comprehensive keys that are very easy to use. The prices for these keys are very reasonable, and the publisher will send any of them on fifteen days' approval. These keys are available with spiral or cloth binding, but experience has shown that the spiral bound keys are far superior because they open flatter and "keep their place" far better. Prices are quoted for spiral binding.

PICTURE-KEY NATURE SERIES

Bauerg, H. How to Know the Western Trees. Dubuque, Iowa: William C. Brown Company, 1955. ($2.00)

Booth, Ernest S. How to Know the Mammals. Dubuque, Iowa: William C. Brown Company, 1949. ($2.50)

Chu, Hung-Fu. How to Know the Immature Insects. Dubuque, Iowa: William C. Brown Company, 1949. ($2.50)

Conard, Henry S. How to Know the Mosses and Liverworts. Dubuque, Iowa: William C. Brown Company, 1956. ($2.50)

Cuthbert, Mabel J. How to Know the Spring Flowers. Dubuque, Iowa: William C. Brown Company, 1949. ($2.00)

Cuthbert, Mabel J. How to Know the Fall Flowers. Dubuque, Iowa: William C. Brown Company, 1948. ($2.00)

Eddy, Samuel. How to Know the Fresh-Water Fishes. Dubuque, Iowa: William C. Brown Company, to be published in 1957. (price unknown)

Jahn, Theodore L. How to Know the Protozoa. Dubuque, Iowa: William C. Brown Company, 1949. ($2.50)

Jaques, H. E. How to Know the Insects. Dubuque, Iowa: William C. Brown Company, 1947. ($2.00)

Jaques, H. E. How to Know the Beetles. Dubuque, Iowa: William C. Brown Company, 1951. ($3.50).

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Jaques, H. E. How to Know the Land Birds. Dubuque, Iowa: William C. Brown Company, 1947. ($2.00)

Kaston, B. I. How to Know the Spiders. Dubuque, Iowa: William C. Brown Company, 1952. ($2.50)

Pohl, R. W. How to Know the Grasses. Dubuque, Iowa: William C. Brown Company, 1953. ($2.25)

Prescott, G. W. How to Know the Fresh-Water Algae. Dubuque, Iowa: William C. Brown Company, 1954. ($2.25)

Additional References

Pennak, Robert W. Fresh-Water Invertebrates of the United States. New York: Ronald Press Company, 1953. (14.00)

Although the price of this book is rather high, it is one of the most comprehensive and worthwhile books in print which deals with aquatic invertebrates.

Driver, Ernest C. Name That Animal. 119 Prospect Street, Northampton, Massachusetts, 1950. ($6.50)

This is an excellent reference book to have in any high school library. It contains illustrated comprehensive keys to most of the animal groups and is especially valuable as a supplement to the Picture-Key Nature Series since it has very good keys to the reptiles and amphibians of the United States.

VITA

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