Roles of herbaria in plant systematic studies

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To begin with: No plant systematics without herbaria. That is true for classical, morphological systematics, and also for modern, molecular, systematics. Plant systematics is the discipline of ordering plants into categories, naming as well the categories as the plants. For the categories we have the convention that the species is the basic category. Related species are placed in genera, related genera in families. Each family has a name, each species has two names, that of the genus and the species epithet.

The aim of plant systematics is knowledge of plants. Knowledge that can be communicated. Knowledge that is necessary especially for international communication. Where would horticulture, forestry, pharmaceutics, ecology and physiology be without systematics? Darwin build his evolution theory on the systematics of plants and animals. So systematics is basic to many other sciences but also has many practical implications, also in international commerce.

To be able to give every species a name we need an archive of plant specimens.

The problem is that nature is variable. It is impossible to describe and name one plant, and decide that all similar plants belong to that species. In reality we study many collections of plants, generally not two of them identical. If we find a gap between one group of collections and another group, we may decide that we deal with two different species, each of which we can give a name.

As Plant Systematics with its system of binary names originated with the Species Plantarum of Linnaeus, in 1753, plant systematists are nearly 250 year engaged in the study and naming of species. Several families have been revised two or three times, but we are far from a final system. That is because,

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especially in the tropics, new species still are being found, but also because our knowledge of plants increases. For instance the study on DNA contributes to the study of morphology and other disciplines used for systematics. Intuitively I myself have made a new system of Magnoliaceae, reducing the number of genera. The study of DNA has not only confirmed my system, but indicates that the whole subfamily Magnoliioideae possibly consists of only one genus.

The collections we study form our archive and are deposited in herbaria. Without that archive plant systematics would not be possible. If someone studies the DNA sequence of species of Magnoliaceae, he has to make voucher specimens. If he does not make vouchers, his work can not be verified. If in a paper, or a thesis, a new system is published based on DNA, it is scientifically meaningless if there are no vouchers. If the author was mistaken in an identification, his results are erroneous. The only control we have is the voucher collection. Important DNA work will be used for many years in the future. And all those years it will be necessary to verify the names of the species studied. So the herbarium has to be permanent, with facilities to store, guard, and study the collections. Four the conventional plant systematist the herbarium collections are the archive to work with. Conventional Systematics would not be possible without herbaria. But also modern systematics, based on DNA sequences, looses its credibility without an herbarium.

**The daily word of the plant taxonomist**

The task of the plant taxonomist is to classify plants. In nature plants occur in populations of individuals who, together, form a breeding unit. Populations that are capable of exchanging genes belong to one species and the species, therefore, is the fundamental unit of plant taxonomy. The species is the basic taxon with which we work. Species resembling each other we join together in a genus, genera in a family, etcetera. Not all populations of a species are identical. Especially when species grow in a large area populations in different parts or with slightly different ecology may differ considerably from each other. Yet they still are capable of exchanging genes thus remaining member of the same species. As soon as a barrier is formed, preventing further exchange of genes, a species may separate into two different species. The great problem for the taxonomist is that, regarding the pattern of variation, all transitions exist
between populations of one species and different, genetically isolated, species. One of the reasons is that new species still are in the process of evolving. This makes the work of the taxonomist, whose task it is to classify plants into species, so difficult. If one works on taxa of areas that are under-collected we often even do not know the chromosome number, let alone that we know whether populations with lesser or greater morphological differences are genetically isolated. In many cases populations are not known, only individuals. How does a taxonomist work to come to a classification? First of all he needs a herbarium. Normally the herbarium he works in has not enough collections of his group, so he has to borrow collections from other herbaria. If he does not work in an officially recognised herbarium, borrowing of specimens is difficult or impossible. After he received as many collections as possible, he starts putting the specimens on piles. In genera with easy to recognise species, he will soon arrive at as many piles as species, and he can start making his descriptions. But in the more difficult genera, piles are repeatedly united and separated. So called complex species or species complexes may exist of dozens of taxa all having transitions. The whole complex forms a continuum with a huge variability. In the case that we only have herbarium material at our disposal the task becomes quite impossible.

**Hybridisation**

Sometimes something genetically is the matter. Therefore we have to study the species in the field, count the chromosomes, study the propagation and may find aberrations of the normal pattern. Normal plants possess two sets of chromosomes, 2n. The chromosomes occur in pairs and members of each pair resemble each other very much. When species hybridise the bastard receives two sets of chromosomes that are so different that it is sterile. During the forming of the reproductive cells meiosis takes place so that the ovum and the pollen contain only one set of chromosomes, they are haploid. During meiosis the members of each pair of chromosomes come in close contact and exchange genes. In a bastard, the members of each pair are so different that it is impossible for them to come into close contact and the meiosis is aborted, resulting in the plant being sterile. Sometimes, however, propagation cells are formed with two sets of chromosomes, 2n. If, in very rare cases, a 2n pollen cell fertilises a 2n ovum, the embryo and the resulting plant will be tetraploid, 4n.
And this tetraploid is fertile, because it possesses two sets of chromosomes that resemble each other enough for a good meiosis.

There are examples where species A and species B hybridise and the hybrid forms a tetraploid, AABB. The same happens with species B and C. The two tetraploids are capable of giving sterile hybrids, which sometimes even may give birth to an octoploid. Also between all these taxa sterile hybrids may arise. Even the number of species involved may be much greater.

The plants we used for the research to come to this scheme have to be deposited in a herbarium. If not, we never can be sure that the researcher used the right names for his species, and his research is not reproducible.

**How to delimitate our taxa?**

For delimitation of taxa we use characters. Macro-morphological characters are the characters we can see with the naked eye or a hand-lens. For identification keys we preferably use these characters. For classification and assessing relationships we also use other characters. Chromosomes have been mentioned. Pollen often is important. Pollen is studied by a palynologist. We also use anatomy, studied by an anatomist. Systematic anatomy is a branch of anatomy that studies the anatomical characters in relation with classification. Also chemical characters, studied by the chemotaxonomist, are often relevant for classification. The taxonomist uses the data provided by the specialists in different fields to make a character analysis of his taxa to be used for delimitation and
classification. All the data of the several fields are derived whether from herbarium material or from living plants. In the latter case always voucher specimens should be deposited in a herbarium. Otherwise the study is not reproducible.

**Taxonomy and systematics**

Taxonomy is part of systematics. Taxonomy is pure classification. Systematics also comprises phylogeny. The systematist strives to make a classification that reflects phylogeny. In earlier times that was done using ones feeling. The more taxa resemble each other the closer they are related. In the forties struggle began over biological or taxonomic species. It was the time of the new systematics. The new systematics emphasised the importance of studying living plants in the field. The biological species concept dates from that time. Biological species are species known to form a propagating community. Taxonomic species are species separated by characters recognisable in a herbarium. Numerical taxonomy was introduced in 1973 by Sneath and Sokal through the publication of their book: Numerical Taxonomy. Again a struggle between proponents and opponents. Numerical taxonomy tries to calculate the relationship by using many characters of which a formula was made. With the formula an exact figure could be calculated. Proponents argued that numerical taxonomy was scientific because relationship was calculated in an objective way. In fact, numerical taxonomy was putting into a formula what every taxonomist already did: based on as many characters as possible comparing and delimiting taxa. Later, Hennig published his book Phylogenetic taxonomy (1979). Hennig said that in an analysis of relationship and phylogeny only derived characters may be used, not primitive. He named them apomorph and plesiomorph. If in a species white flowers become red, all the plants with red flowers are more closely related to each other than to plants with white flowers. Hennig supposed that white flowers only once became red in the species. If one has enough characters, and if one knows how they have evolved, one can make a phylogeny of a group. There are four species, 1, 2, 3, and 4. They are all related because they all possess the derived character A (A is derived from a primitive character A, etc.). Species 1 and 2 are narrower related to each other that to 3 and 4, vice versa, because 1 and 2 possess the derived character B', and 3 and 4 the derived character C'.
The method of Hennig, called cladistics, soon became very popular. Computer programs were made to accommodate large numbers of characters and make phylogenies, here called cladograms. In the beginning many plant taxonomists were disappointed, because the programs made hundreds of different cladograms from the set of characters. The computer tries to make trees with as few character transitions as possible, so called parsimonious trees. Nature was supposed to be parsimonious. One speaks of cladograms as being scientific hypotheses that can be verified and falsified. Well, in my opinion a cladogram based on morphological characters can not be verified. We know far to few of the plants involved to verify a phylogeny based on morphological characters. And specially making a cladogram of a group of which one does not know the genetic background, and whether it is a complex of polyploids or not, is totally senseless and therefore not scientific. The more because vascular plants often are of polyploid origin and contain much genetic material. Genes coding for a character may be suppressed by other genes. That means that character analysis can not tell us whether a character is present in the genome or not. Hennig was zoologist, and in my opinion his theory cannot be easily applied to plants.

**Scientific at last**

Nowadays we are able to look at the genetic material itself. Allozyme electrophoresis and DNA sequencing teach us many things regarding relationships. They may serve to test the cladograms based on morphologic characters. But also here we should be watchful. If the principle of parsimony is false, cladograms based on DNA may also give a wrong picture. DNA has the benefit that the number of characters is very high. Each plant contains an enormous...
amount of DNA. So we can make several cladograms and compare them with each other to arrive at a consensus tree. For higher taxa, as families and genera, the results are promising. We shall be obliged to change the classification of many taxa based on the results of DNA sequencing. Magnoliaceae are a great example. In the past I had already merged several genera, which was confirmed by Sangtae Kim’s DNA research. Based on his and other DNA research, it is now nearly certain that the subfamily Magnolioidae contains only one genus. Knowing the results of the DNA research I looked again at the morphology. It appeared that in the past characters were used for delimitation of genera that have evolved many times in the family. So what parsimony?

Conclusion

Also for DNA research plants have to be collected. The identification of the material is crucial for the standing of the research. And it is imperative that the identification can be assessed in the future. Therefore, also of this material voucher specimens have to be kept in a herbarium. The only control we have is the voucher collection. Important DNA work will be used for many years in
the future. And all those years it will be necessary to verify the names of the species studied. So the herbarium has to be permanent, with facilities to store, guard, and study the collections.

Four the conventional plant systematist the herbarium collections are the archive to work with. Conventional systematics would not be possible without herbaria. But also modern systematics, based on DNA sequences, looses its credibility without an herbarium.

I hope that I have succeeded in conveying to you how important herbaria are for all kinds of systematic research.

**Literature Cited**